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# HOME POWER

THE HANDS-ON JOURNAL OF HOME-MADE POWER

Issue #77 June / July 2000

## Features



## Features



## Guerrilla Solar



## GoPower

Cover: Alan Gross and Jane Townsend chose solar to power their Caribbean home, and kept the luxuries of NYC.

## Things that Work!



## Homebrew



## Book Review



## Columns



## More Columns



## Regulars



## Access and Info


**Access Data**

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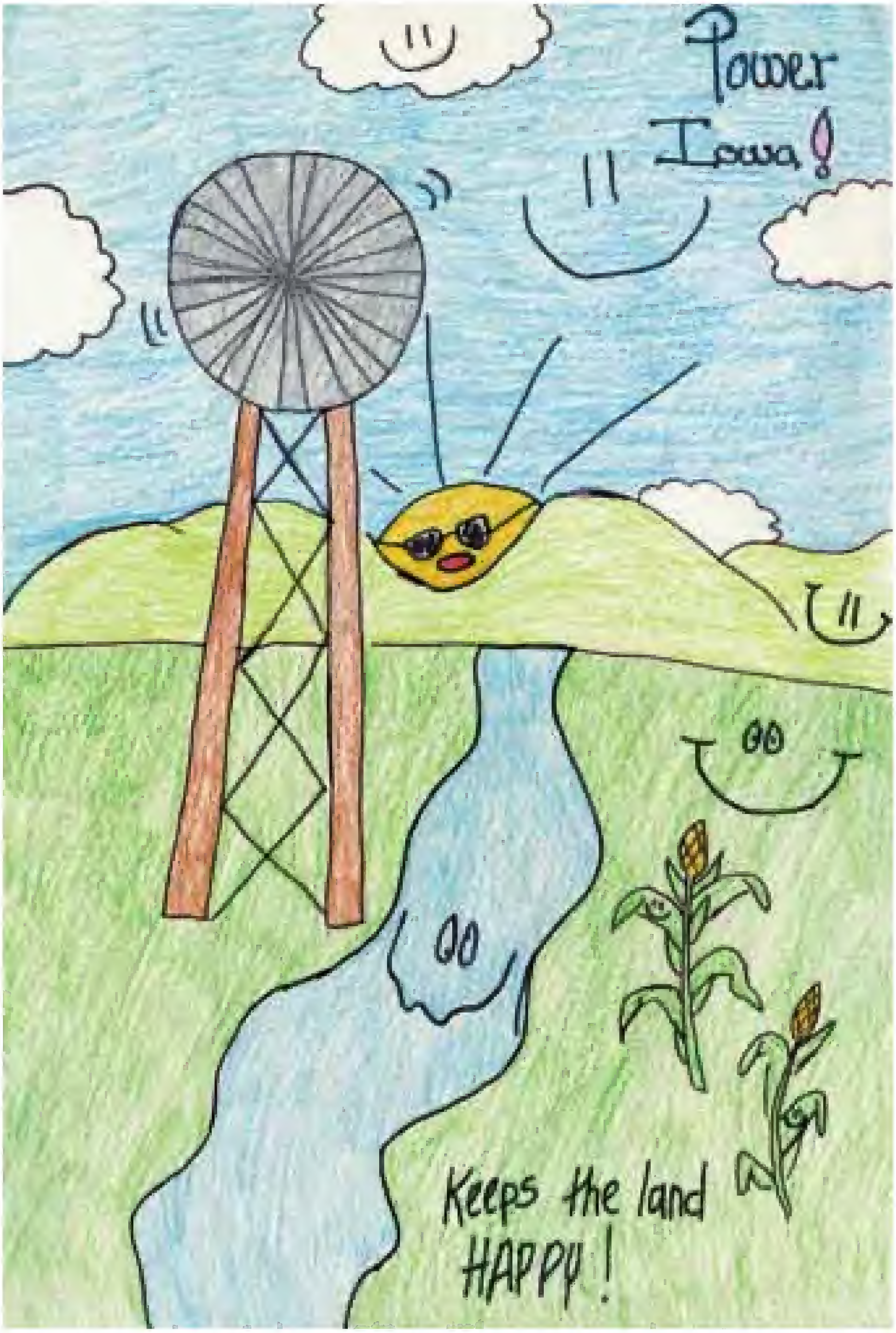


**Kids Promote Renewables**
In January, the Iowa Department of Natural Resources chose Muscatine Power and Water (MP&W) to be part of a community-wide energy efficiency initiative. To kick off this event, MP&W, Iowa's largest municipal utility, had a poster contest. It was modeled after Iowa Energy Center's statewide contest, which focused on energy conservation and efficiency, and replacing fossil fuels with renewables.

MP&W's energy services advisor, John Root (John_Root/MPW%MPW@mpw.org) was the sparkplug behind the MP&W poster contest. He figured that with two contests, "local 4th and 5th grade students would have a double chance of winning."

As the posters began rolling in, John realized that something truly amazing was happening. There were 403 posters! "We filled a room 20 by 30 feet three times while judging the amazing display of energy saving slogans, wind turbines, hydro plants, and solar collectors. It was an incredible experience to see this wonderful, creative, and inspiring artwork," John stated.

We're reprinting Maegen Sides' first place poster, "Keeps the Land Happy," to share with our readers. You can find a downloadable screen saver of the twelve winning posters at www.mpw.org.

—The *Home Power* crew

## People

Joy Anderson
Steve Bell
David Brandt
Mike Brown
Sam Coleman
Alastair Couper
Richard Engel
Alan Gross
Margo Guda
Eric Hansen
Kathleen Jarschke-Schultze
Mini Kroon
Stan Krute
Don Kulha
Don Loweburg
Karen Perez
Richard Perez
Shari Prange
Benjamin Root
Connie Said
Joe Schwartz
Jane Townsend
Michael Welch
John Wiles
Mark W. Wilkerson
Dave Wilmeth
Myna Wilson
Ian Woofenden
Rue Wright
Solar Guerrilla 0010

## "Think about it..."

***All humanity is divided into three classes: those who are immovable, those who are movable, and those who move!***

*-Benjamin Franklin*

# Power Now

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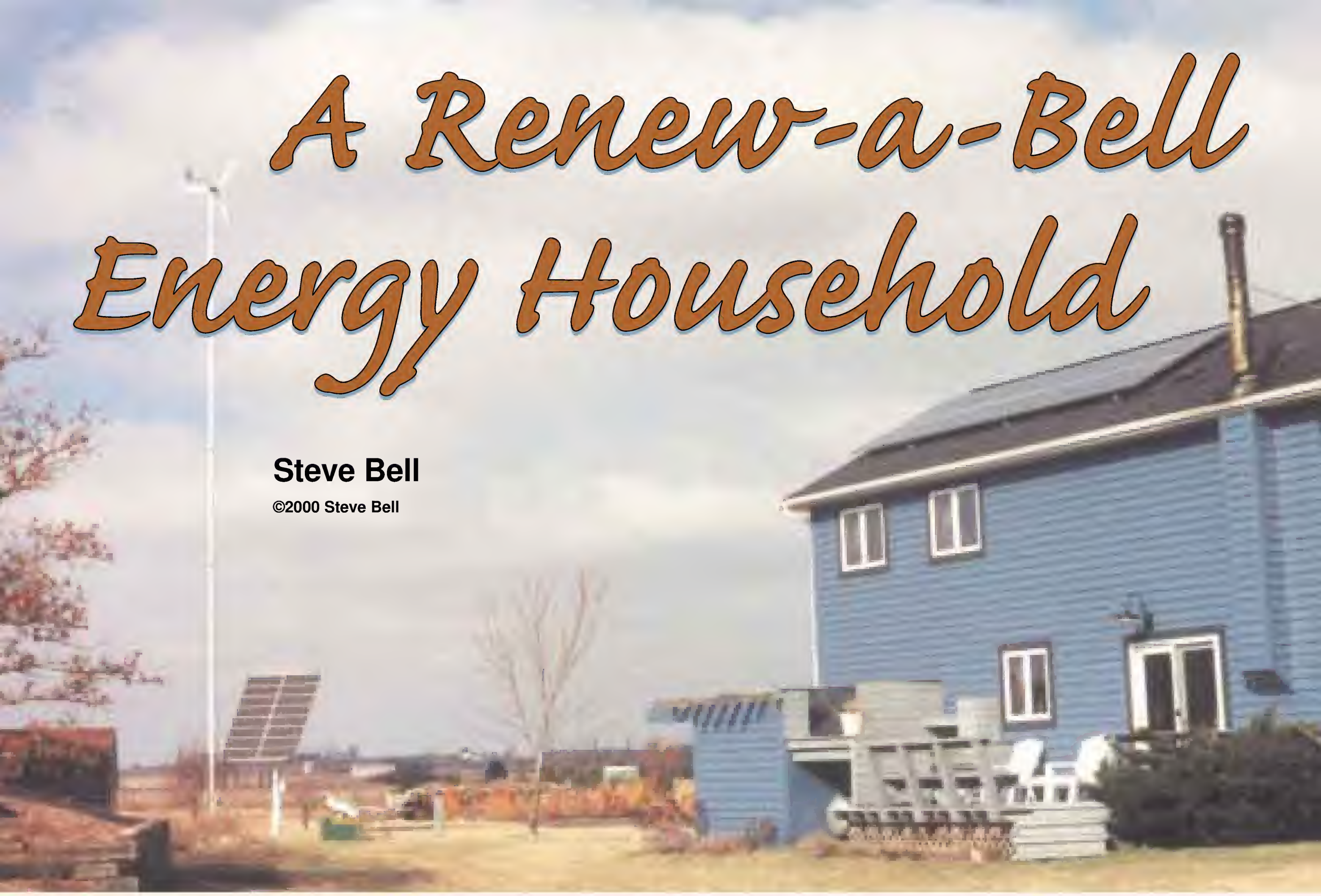
# A Renew-a-Bell Energy Household

**Steve Bell**





**Steve and Jan Bell's home with 2,100 watts of roof-mounted PV, 880 watts of tracked PV, and 3,600 watts of wind power.**

Almost twenty years ago, my wife Jan and I decided we wanted to take more control and responsibility for our lives. We wanted to live in greater harmony with ourselves and nature. We wanted to live lives that lifted our spirits. We were seeking a place that would help us live in a better, more uplifting way. In the mid 1980s, we uprooted our lives, and moved to the tiny village of Stelle, Illinois. Since then, we have been learning what it means to be more responsible, spiritual beings.

### Passive Solar Home

In 1986, we built our passive solar, super-insulated home. The 2,250 square foot (209 m$^2$) house was originally all-electric, with central air conditioning and heat. It has R-28 walls, R-50 ceilings, and R-15 rigid foam insulation on the outside of the concrete basement walls.

Our normal heating is accomplished with a wood burning stove (with catalytic converter). We use two to three cords of wood per year for heating. This is not very much for a house of this size in this location. We only use the electric furnace to keep the house from freezing when we are out of town for several days or more.

The insulation on the outside of the basement walls makes the concrete walls (75+ tons) into a large thermal mass that significantly reduces temperature fluctuations. Most of the windows are on the south and east sides of the building. This allows for good solar gain during the morning and through mid-afternoon. By aiming the long south axis of the house about 20 degrees east of due south, the south wall is perpendicular to the sun at about 11 AM rather than at 12 noon. This helps with a quick morning warm-up of the house (when it is needed), and helps reduce late afternoon overheating.

The windows in all of the rooms are configured to allow good cross-ventilation. All the windows have low-E coatings to reflect infrared radiation (heat). This keeps the heat in during the winter and out during the summer. Normally, we only use the air conditioning for four to six days per summer, during hot spells when the

humidity is high and it only cools off to 85°F (29°C) at night. For the rest of the time, ceiling fans are enough.

**MREA Provides RE Inspiration**

When we designed and built the house, we thought that renewable energy (RE) was too expensive to realistically consider. Enter the Midwest Renewable Energy Association (MREA). In the early 1990s, we started attending the annual MREA Energy Fair in Amherst, Wisconsin. We became much more educated about the realities of RE. In 1994, we started our RE system by ordering a 4 KW remanufactured direct-drive Jacobs wind turbine and a 115 foot (35 m) custom-built, tilt-up tower kit. We purchased a Trace SW4048 inverter and sixteen Trojan L-16 batteries.

By the summer of 1996, the tower and wind turbine were installed. We normally have a good wind resource from October through mid-June; during the summer, the winds are light and variable. This provided enough power in the winter months for much of our 120 VAC loads, but was very lacking in the summer months.

We decided to make our home mostly energy independent by adding PV to our RE system, and by eliminating most of the 240 VAC loads. In September of 1997, we installed sixteen Siemens SM55J modules (880 watts) on a dual-axis Wattsun tracker. In 1998, we replaced the ten year old 22 cubic foot (0.62 $m^3$) refrigerator/freezer with a new high efficiency 22 cubic foot Amana refrigerator/freezer (Model BR22S6) that uses 1.4 KWH per day.

Then we started planning our conversion from 240 VAC to LP gas. First, we replaced the electric cooktop with an LP unit. We are in the final stages of installing an AquaStar 125BS on-demand propane water heater. We will be using the old electric water heaters as pre-heat tanks with 48 VDC elements for dump loads. The only 240 VAC loads we will retain are the central air conditioning and a Kitchen Aid double oven. Both these loads are rarely used, but are nice to have available.

**Grant Provides Incentive**

In early 1999, Illinois announced its grant and rebate program. The program pays up to 60 percent of the cost of a PV system. We decided to request a grant for an additional twenty-eight roof-mounted Siemens SP75 modules (2,100 watts), along with an SW5548 inverter, two MPPT controllers, an E-Meter, a DeSulfator, and twenty-four Concorde PVX-12255 batteries. The grant was approved, but they would not cover the cost of the batteries. The program managers decided that they would not pay for a wear item that the end-user could ruin in a short number of years.

During the summer of 1999, we installed the additions, including the larger battery bank. Since then we have always produced more power than we've needed. Our electric bills are now quite low, and should drop to little more than the basic service charge when the AquaStar goes on line. Water heating is our major utility load—abundant hot water is one of our luxuries.

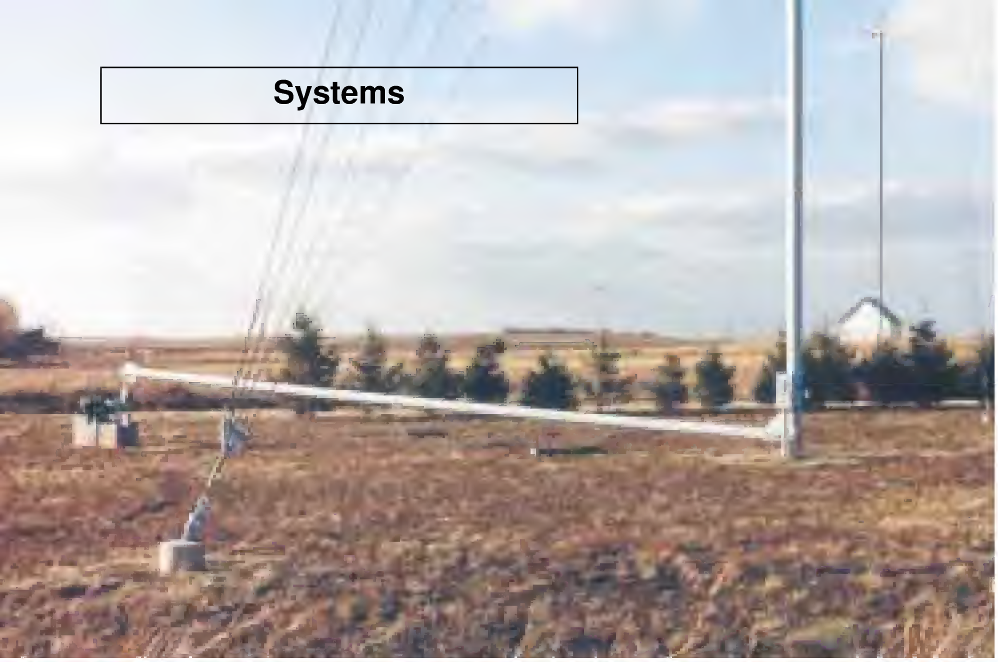
In 1994, our daily electric utility consumption was 43.6 KWH per day. Since the system upgrade last summer, our daily consumption is down to 17.1 KWH per day. Out of that total, I estimate that about 15 KWH is consumed by the water heaters. The figure is high because we are presently heating the hot water with electricity. We hope to use surplus RE energy and LP gas in the future, and four large flat-plate solar hot water panels that I plan to install someday.

**Wind Turbine**

The wind turbine generates a nominal 48 VDC, and is adjusted to govern at about 3,600 watts. This Jacobs "long case" wind turbine (circa 1940) has a 14 foot (4.3 m) diameter, 3 blade rotor. It's mounted on a custom-built 115 foot (35 m) tilt-up tower. The tower kit was designed by Mick Sagrillo, and assembled on the site.

I think it is the largest (heaviest) tilt-up tower that Mick has designed. It consists of four sections of 8 inch

**The '40s era Jacobs wind generator (right) on its 115 foot tilt-up tower. The 10 KW Bergey Excel (left) helps power the community water treatment plant.**



Five sets of guy wires attach to each anchor of the huge tilt-up tower.

schedule 40 steel pipe, with large, welded flange plates and a 7 foot (2.1 m) stub tower. There are five sets of guy wires, 16 cubic yards of concrete in the anchors and piers, and a custom made block and tackle assembly that could serve for a small crane.

The Jake is one of Mick's remanufactured units. Its output is fed underground through a pair of #2/0 (67 $mm^2$) USE copper cables to the battery bank. The total one-way wire run is almost 450 feet (137 m). There is a fused disconnect, with a lightning arrestor, at the base of the tower. A 150 amp, 250 volt diode at the battery end keeps the DC generator from becoming a DC motor. There is a 100 amp/50 millivolt shunt with a 100 amp analog ammeter to measure delivered power.

## PV Arrays

We mounted sixteen Siemens SM-55J modules (four subarrays) on a Wattsun dual-axis tracker. Each subarray has a blocking diode on its output. The four 48 volt subarrays are wired to an individually fused combiner box (with lightning arrestor) mounted on the tracker pole. We fed the array output underground to a 20 amp DC breaker at the battery bank using about 120 feet (37 m) of #4 (21 $mm^2$) USE cable.

The winch, with block and tackle, at the gin pole.

There are twenty-eight SP-75 modules on our roof. Seven subarrays feed into an individually fused combiner box (with lightning arrestors). The seven outputs are combined into two main 48 volt subarrays—one of 900 watts and the other of 1,200 watts. The 1,200 watt subarray uses 70 feet (21 m) of #4 (21 $mm^2$) cable to connect to a Solar Converters MPPT controller (#PT48-20M) via a 60 amp DC breaker. The 900 watt subarray uses 70 feet of #6 (13 $mm^2$) cable to connect to its MPPT controller (same model) via another 60 amp DC breaker.

## Charge Controllers

Both the outputs of the Jacobs and the 880 watt tracked PV array are connected, via blocking diodes, directly to the DC bus bars. The output of the 2,100 watts of roof-mounted PV is connected to the Solar Converters MPPT charge controllers, which connect to the DC bus bars. There are DC breakers or fused disconnects on all three charging systems.

Two MPPT charge controllers prevent overcharging by the two roof-mounted PV arrays.

A pair of C-40s (acting as diversion controllers) regulates the battery bank voltage. They dump excess power into a pair of home-built, heavy-duty, resistive hot-air heaters. The C-40s are connected to the battery bank via a 110 amp class-T fuse with parallel #2 (33 $mm^2$) cable from the fuse to the dump load.

Basically, I regulate my batteries with a load rather than regulating my charging source. I dump all the wind power (and the power from the PV array) directly into my batteries and then add loads to control voltage. Battery state of charge is tracked via an E-Meter, with the shunt installed between the batteries and the negative bus bar. I installed a DS-1000 battery DeSulfator (a sweep-pulsing desulfating device for larger battery banks) to help protect against sulfation.

**Grounding**

If your PVs are roof-mounted, or operate above 50 VDC, the *NEC* requires that the negative DC conductor be grounded. I have my doubts about this. If both the positive and the negative wires are allowed to “float” (are not grounded), then the only thing that they are “hot” to (read “dangerous”) is each other. You could put one wire in your mouth and stand in a puddle and not be shocked. The only danger is if you are touching both wires at the same time.

The *NEC* requires you to ground the negative leg, thus making the whole world electrically common with the negative leg. Then if you touch anything while touching the positive leg, you can get shocked. The *NEC* says this is safer.

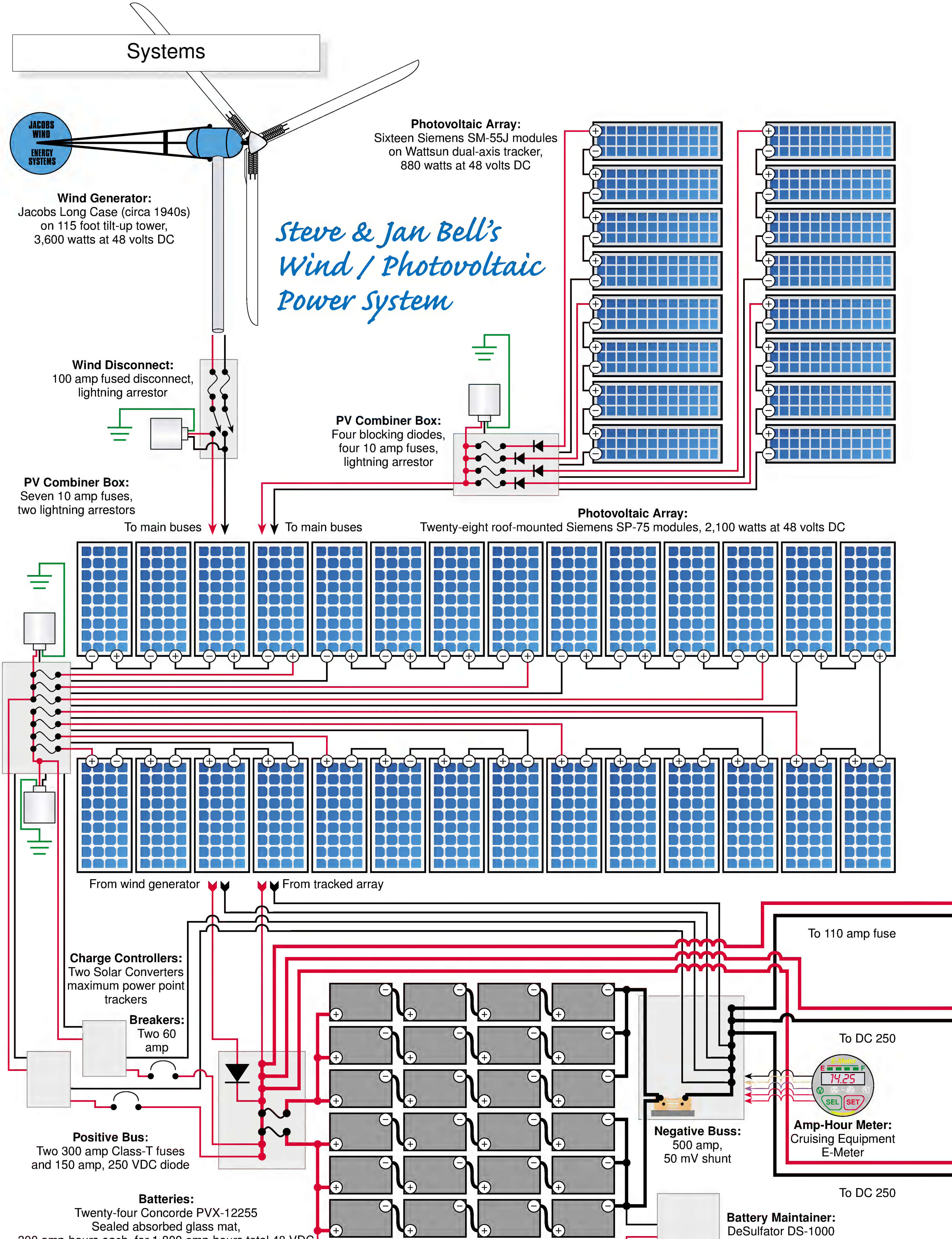
The code requires you to ground the negative leg on roof-mounted PV arrays, and to add a ground-fault interrupter (read “extra expense”). This is to insure that the grounded negative leg does not cause a house fire should there be a failure of the grounded negative leg. With a “floating” (non-grounded) DC system, this type of fire cannot happen. I do believe in very good equipment grounding for lightning protection and safety. And very good AC grounding is important because the U.S. grid is grounded, and because many AC appliances are designed with that grounding in mind.

All the electrical equipment chassis are grounded to the AC ground. The windmill tower has ground rods on all four guy anchors and at the tower base. A #4 (21 $mm^2$) bare copper wire runs up the inside of the tower all the way to the top stub tower. This means that there is very low resistance from the tower top to earth ground, avoiding increased resistance where the painted tower flanges bolt together.

**Twenty-four Concorde SunXtender sealed absorbed glass mat batteries provide 1,800 amp-hours at 48 VDC.**

The PV frames, tracker rack, and pole are very well earth grounded. The roof racks and module frames are bonded and tied to the house lightning protection system, which is a very good ground. I have both Delta lightning arrestors and surge capacitors on the AC utility lines, and an arrestor on the home side of the AC (inverter AC output).

**L–R: Dump load, two Trace C-40 shunt regulators, utility grid breaker, AC subpanel, grid/RE transfer switch, Trace 4048 and 5548 inverters with DC 250.**


JACOBS WIND ENERGY SYSTEMS
Wind Generator:
Jacobs Long Case (circa 1940s)
on 115 foot tilt-up tower,
3,600 watts at 48 volts DC
Photovoltaic Array:
Sixteen Siemens SM-55J modules
on Wattsun dual-axis tracker,
880 watts at 48 volts DC
Steve & Jan Bell's
Wind / Photovoltaic
Power System
Wind Disconnect:
100 amp fused disconnect,
lightning arrestor
PV Combiner Box:
Four blocking diodes,
four 10 amp fuses,
lightning arrestor
PV Combiner Box:
Seven 10 amp fuses,
two lightning arrestors
To main buses
To main buses
Photovoltaic Array:
Twenty-eight roof-mounted Siemens SP-75 modules, 2,100 watts at 48 volts DC
From wind generator
From tracked array
To 110 amp fuse
Charge Controllers:
Two Solar Converters
maximum power point
trackers
Breakers:
Two 60
amp
To DC 250
Positive Bus:
Two 300 amp Class-T fuses
and 150 amp, 250 VDC diode
Negative Buss:
500 amp,
50 mV shunt
Amp-Hour Meter:
Cruising Equipment
E-Meter
SEL
SET
14.25
To DC 250
Batteries:
Twenty-four Concorde PVX-12255
Sealed absorbed glass mat,
300 amp-hours each, for 1,800 amp-hours total 48 VDC
Battery Maintainer:
DeSulfator DS-1000

Who are all these solar bozos?

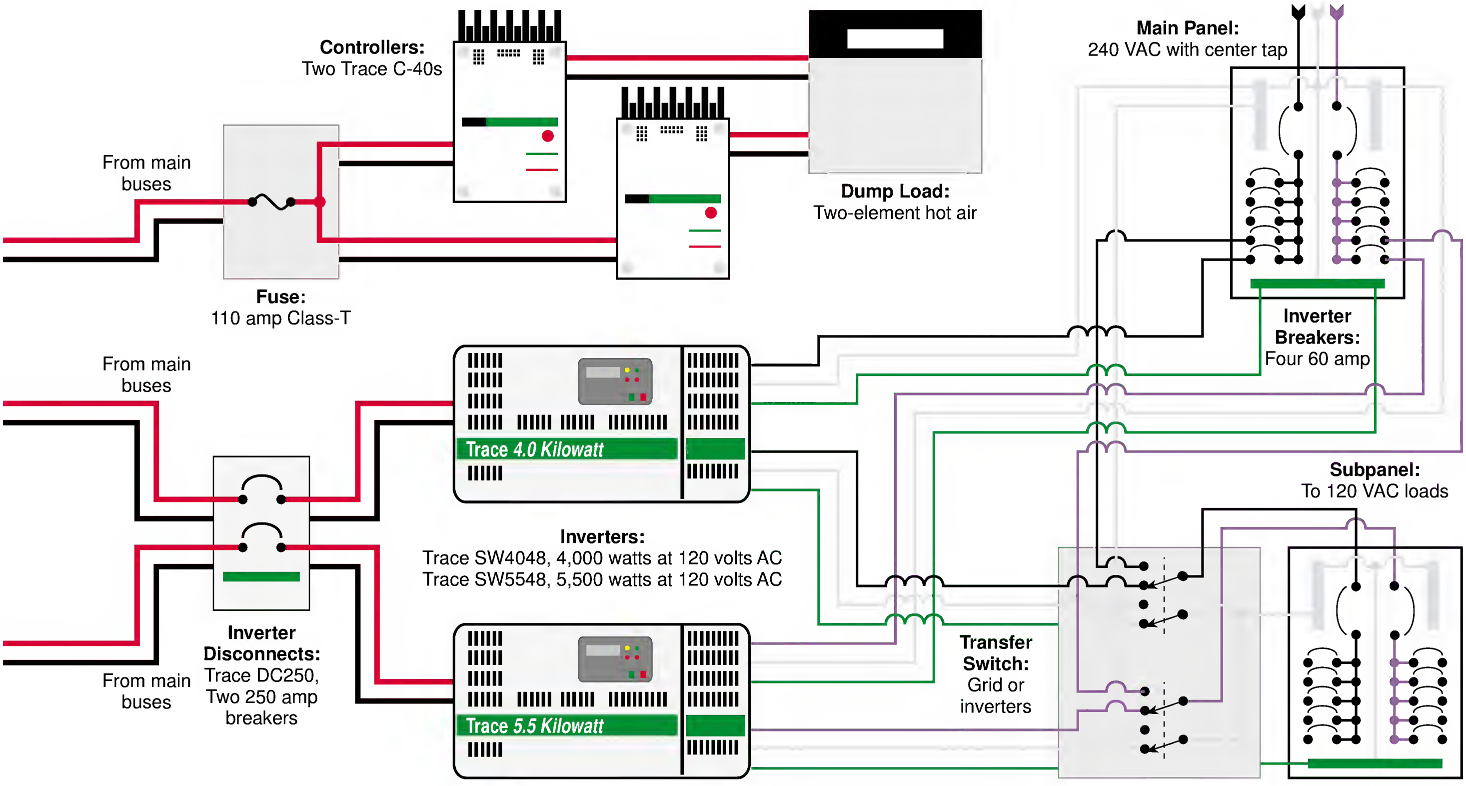
### Batteries

The battery bank was originally sixteen L-16s with Hydrocaps. Now it is twenty four absorbed glass mat (AGM) Concorde SunXtender PVX-12255 batteries. Each sealed battery is 12 VDC, 300 AH at the 100 hour rate, and weighs 162 lbs. They are wired in series with #2/0 (67 $mm^2$) cable, and are paralleled with #4/0 (107 $mm^2$) cable.

Because of physical layout considerations, the batteries are configured in two groups of twelve. These are both wired in parallel to the same solid copper positive and negative bus bars. Each twelve-battery grouping is configured as three parallel 48 VDC battery strings. The two sub-banks are tied to the bus bar through a pair of 300 amp class-T fuses. The batteries in each sub-bank are cross-tied with #4 (21 $mm^2$) cable to help balance charging. The E-Meter tracks all the power in and out of the battery bank. The DS-1000 DeSulfator should help control battery sulfation.

### Inverters

The two inverters, which are not stacked, power all the 120 VAC loads in our home. Each inverter generates pure 60 Hz, 120 VAC sine wave electricity (3–5% THD). These inverters are really power conversion centers. They not only convert battery voltage into sine wave household voltage, but are also capable of recharging the batteries from a backup generator or from utility power. They can also sell excess power back to the utility.



**Bell System Costs**

*Wind System*

| Item | Cost (US$) |
|---|---|
| Jacobs wind turbine* | $6,500 |
| Tower kit, including 7 foot stub tower* | 6,088 |
| Sandblasting and painting* | 1,160 |
| 1,000 feet #2/0 USE cable | 1,126 |
| Concrete | 1,120 |
| Welding* | 1,000 |
| 8,000 pound 48 VDC winch | 1,000 |
| 108 feet of 8 inch schedule 40 steel pipe | 800 |
| Trenching and backhoe* | 525 |
| Two C-40 diversion controllers | 280 |
| Miscellaneous hardware | 200 |
| Fused disconnect box | 120 |
| Heavy duty dump load, home-built | 0 |

*Tracker PV System*

| | |
|---|---|
| 16 Siemens SM-55J solar modules | $5,040 |
| Wattsun dual-axis tracker | 1,660 |
| Concrete | 280 |
| Wiring and conduit | 250 |
| Fused combiner box | 120 |
| 20 feet of 6 inch schedule 40 steel pipe | 100 |

*Roof PV System*

| | |
|---|---|
| 28 Siemens SP-75 solar modules | $10,136 |
| Module mounting racks | 964 |
| 2 Solar Converters MPPT charge controllers | 616 |
| Fused combiner box | 270 |
| Wiring and conduit | 250 |

*Battery Storage System*

| | |
|---|---|
| 24 Concorde PVX-12255 batteries | $8,585 |
| Battery box materials | 470 |
| Battery cables | 450 |
| E-Meter with pre-scaler | 270 |
| DeSulfator, DS-1000 | 113 |
| Safety fusing | 90 |
| Miscellaneous cable and conduit | 70 |

*Inverters & AC System*

| | |
|---|---|
| Trace SW5548 with conduit box | $2,885 |
| Trace SW4048 with conduit box | 2,460 |
| Dual DC250 with additional breakers | 442 |
| Manual AC transfer switch | 150 |
| Miscellaneous wiring and conduit | 125 |
| AC subpanel | 40 |

| | |
|---|---|
| Illinois sales tax ($40,482 total taxable) | $2,530 |
| *Total System Cost* | $58,285 |

* 6.25% sales tax does not apply to these items.

## Illinois State Incentive Money for RE

The Department of Commerce and Community Affairs (DCCA) of the State of Illinois has begun one of the most RE-friendly incentive programs in the country.

The DCCA administers the Renewable Energy Resources Program (RERP) in order to foster investment in and development of renewable energy resources within the state of Illinois. The RERP will fund projects focused on increasing the utilization of renewable energy technologies in Illinois (estimated at US$5 million per year for five years pending legislative changes). RERP will include wind, solar, thermal energy, photovoltaic systems, dedicated crops grown for energy production, organic waste biomass, and hydropower that does not involve new construction or significant expansion of hydropower dams.

There are two components to the program—grants and rebates. To apply for a grant or rebate, a potential recipient must be within the service territory of an investor-owned electric or gas utility, a municipal gas or electric utility, or an electric cooperative that imposes the Renewable Energy Resources and Coal Technology Development Assistance Charge (as defined in Public Act 90-561).

**Grant funding categories are as follows:**

- Wind—50 percent, with a maximum grant of US$300,000
- Solar Thermal—50 percent, with a maximum of US$150,000
- PV—60 percent, up to US$6 per watt with a maximum of US$300,000
- Crops—50 percent, with a maximum of US$150,000
- Organic Waste Biomass—50 percent, with a maximum of US$550,000
- Hydropower—50 percent, with a maximum of US$1,000,000

**Rebates are funded as follows:**

- Solar Thermal—50 percent, with a maximum rebate of US$5,000
- PV—60 percent, up to a maximum of US$6 per watt, with a maximum rebate of US$5,000

*Note: Steve Bell was the first grant recipient in the state. Mark Wilkerson, whose related article is on page 20, was the first rebate recipient. Much hurdle clearing has been done for anyone else in the state interested in this very generous incentive to "go solar."*

The inverters get their DC input via two 250 amp DC breakers connected to the positive bus bar with #4/0 (107 $mm^2$) cable. The two inverters (SW4048 and SW5548) are not stacked, although they can be if I have the need. Each inverter powers one side of the AC subpanel (There are no 220 VAC loads on the system). With a minor wiring adjustment, either inverter is capable of powering the entire household should one of them fail.

Each inverter has access to grid power via its own 60 amp breaker in the utility breaker panel. The AC output of the inverters is fed into a manual transfer switch, which then feeds the sub-panel. A separate pair of 60 amp breakers in the main (utility) panel also feeds power to the manual transfer switch. That allows easy transfer of the subpanel (house loads) back onto grid power should the RE act up.

**Loads**

This system provides power for all the 120 VAC loads in our home. These loads include two freezers, a 22 cubic foot (0.62 $m^3$) refrigerator/freezer, 1/3 hp sump pump, 32 inch (81 cm) color TV, 150 watt stereo, microwave, all the lighting loads, and anything else we plug into the wall.

The battery storage bank can supply the household needs for six to eight days of no wind or PV power before it requires recharging from an outside source. The AC power supplied from the inverter is cleaner than the power supplied from the utility; there are no brownouts, surges, spikes, or power outages.

**Stewards**

Over the years, many people have asked why we chose to go with RE—what is the payback? I explain that economic payback was not a significant consideration when making this choice. Our choice was based on the desire to be better stewards of the planet, and to increase our sense of self-empowerment (taking more direct responsibility for our lives).

We in the RE community are the "way-showers" of a new way of being and living. We are willing to accept the added economic cost of using RE in order to demonstrate in our lives that RE is a practical choice and a livable reality. We are the future!

**Access**

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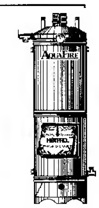
www.commerce.state.il.us








Let there be light.

innovation


simplicity

reliability

No trees were harmed to create this photo.  The markings are created digitally.

# The Solar Capital of the Midwest

Mark W. Wilkerson



The Stelle community phone system (foreground) utilizes 2,900 watts of PV.

Stelle, Illinois may well have become the solar capital of North America, if not the world. Over a third of the homes in Stelle have some or all of their electricity provided by photovoltaics (PV). The town water, phone, and internet service is powered by renewable energy (RE). In total, twenty RE systems on forty acres of land in rural Illinois must qualify Stelle as a most unique hub of RE technology.

Stelle (rhymes with bell) was first recognized as a centerpiece of solar activity in 1996. This small unincorporated village of 110 people is located among thousands of acres of cornfields about an hour and a half south of Chicago. In the last four years, it has manifested even more evidence of an unspoken philosophy of living which seems to be shared by most residents here.

**Solar Phone Company**

First let's look at the town's infrastructure. North America's first off-grid solar-powered phone company is celebrating five years of 100 percent system reliability. Each resident of Stelle owns a share of the Stelle Telephone Company, a rural mutual cooperative. Every phone call made from Stelle is in fact a solar-powered phone call.

The decision to go solar was made because of power quality and availability problems with the electric utility serving the community. The electricity supply to rural locations is more susceptible to lightning strikes, ice storms, and other natural phenomena. The 200-line digital phone switch would be severely impacted every time a glitch occurred, and no phone calls could be made or received.

That problem has been solved with a 2 KW peak array of Solarex MSX-64 solar modules, and a large bank of sealed absorbed glass mat batteries (1,400 amp-hours at 48 VDC) in conjunction with a backup propane generator. The generator was designed to run approximately 150 hours per year (one oil change/maintenance interval), and it has fallen within 5 percent of the designed run time.

Perhaps the owners of Stelle Telephone have not seen a direct economic payback, per se. However, can you put a price on having a reliable phone system when you need to make a call? The system has been a definite winner.

**Internet Connection**
Another challenge to a remote community and a rural phone company is access to the Internet. Any phone call made from Stelle to any location outside of Stelle is a long distance call. This little fact of life posed a great challenge to many community members and home-based businesses wanting to use the Internet as an information and communication source. In the summer of 1998, Stelle Telephone became the world's first off-grid solar-powered Internet service provider (ISP). Residents now have extremely reliable Internet connection via two-way satellite TCP/IP connectivity.

The system is supported by a 24 hours per day, 7 days a week network operation center hosting our Internet servers, with data warehousing and backup facilities near San Francisco, California. An additional 900 watts of Siemens solar modules on a Wattsun dual-axis tracker were added to the Stelle Phone Company's central office system. This offsets the additional electrical loads of the on-site equipment, which includes a Cisco server, sixteen 56K modems, and a desktop computer.

These two solar applications have made it possible for many home-based businesses to thrive in Stelle. They have also opened the door for a regional office of the New York based SunWize Technologies to use Stelle as a base of worldwide business development activities. SunWize employs three residents of this small town, and supplies a Stelle-based dealer, Tim Wilhelm of Wilhelm Engineering, with his wholesale solar needs. Tim also runs Stelle Telephone, and teaches electronics and *NEC* courses at a local community college in his spare time.

**Central Water Plant**
Most rural residents live with an individual well and pump. Stelle has a central water plant, instead of 44 individual wells and pumps. (There are 44 living units in Stelle, a mixture of single family, duplex, and quadplexes.) The water plant is owned and run by the Stelle Community Association (SCA). A typical water bill is US$40–60 per month.

Not only is the efficiency of water delivery from one 300 foot (91 m) deep well improved, but the pumps for operation of the plant are all powered by a 10 KW Bergey wind turbine. The wind system was originally set up as a grid-intertied system, so excess power would be sold back to the utility. But since Illinois has

**A 10 KW Bergey Excel powers the town water supply.**

yet to enact a net metering law, the cost and hassle of selling back to the electric company did not make the exercise worthwhile. With a grid-tied system, the load goes down when the grid goes down, so the town has decided to take the water plant totally off-grid.

The association just completed the installation of a battery bank along with a stacked pair of Trace SW5548s and all the hardware in between. With the new incentives (grants and rebates from the state's Department of Commerce and Community Affairs) to use PV in Illinois, a solar-electric system is being considered to add to the reliability of the power supply.

Commonwealth Edison, the state's largest utility, has committed to a net metering policy with hopes of having it enacted by Spring, 2000. The new people in the utility's renewables division are hardworking individuals committed to facilitating a sustainable solar business throughout their service territory. Stelle has been mentioned by one of ComEd's T&D managers as a probable site for using renewables for end-of-grid support. These folks deserve a hand for energizing the

Linea Bara's home sports eight Arco Solar 16-2000 PV panels.

### Systems Large & Small

The smallest residential PV systems in Stelle have small arrays of fifteen year old Arco Solar 16-2000s. These panels were recycled thanks to the sharp eye of Steve Bell, a town resident as well as technical support specialist with SunWize.

The small systems feature eight 16-2000s (35 watts original rating), a Trace UX1112 SB, four Concorde PVX12210 AGM batteries, and a ProStar 30 charge controller with meter. The fifteen year old modules still generate over 90 percent of their nameplate rating.

giant utility (one of the nation's largest nuclear utilities) to adopt new ways of thinking about energy.

### Individual Commitment

The community of Stelle, as a whole, is obviously committed to a solar lifestyle, but what about individual residents? In this town of forty-four living units, there are fourteen homes that have all or part of their electricity supplied by PVs. Another six homes have passive solar features, which offset a good part of the winter heating requirement. More than half of the homes use wood as all or part of their heating fuel. And more PV and passive solar systems are planned.

Another recent trend is the use of propane as the primary fuel for previously electric loads. Having on-site storage allows for an extra measure of autonomy during extended power outages. To be able to use expensive photovoltaic technology appropriately, the use of propane makes sense as a starting point. Most RE system owners cannot afford to burn solar-generated electricity for cooking or heating hot water.

I view propane as a "solar enabler," since it allows us to make steps toward a full solar lifestyle. As appliances improve, fuel cells come on the market, and other technologies emerge, propane can be phased out. The total pollution or negative impact on the planet per KWH of fossil fuel or nuclear generated energy is much greater than a similar quantity of energy used from propane at the point of use.

The largest system in town is Steve's personal wind/PV hybrid system (see page 8). His system includes 2,980 watts of Siemens modules—880 watts on a Wattsun tracker and 2,100 watts on the roof—and a 4 KW Jacobs wind turbine. These supply 48 VDC power to a battery bank of twenty-four PVX-1225s (almost 100 KWH of storage at 48 VDC), along with two Trace inverters (a 4048 and a 5548).

Steve actually has reached a point where excess electricity is available year-round. Since there is no incentive to pump this excess back to the grid, Steve actually heats his basement in the winter by channeling the excess wind generated energy into a set of home-made resistant air heating elements. When it's sunny and windy, Steve can also pre-heat his domestic hot water. Talk about tweaking out the efficiency of a

Steve and Jan Bell's system has 2,980 watts of PV and a 3.6 KW wind generator. See the article on page 8 for a complete description of the system.

system! Steve is also pushing the envelope by experimenting with maximum power point tracking controllers and battery desulfation.

**Straw Bale Neighbor**

This unique strain of solar mania is not all contained within the borders of Stelle's 200 acres. The nearby Haeme family completed their straw bale home several years ago. It was Illinois' first bale building, and since then, Jon Haeme has built another home of straw for a resident of nearby Kankakee County.

Russ Hardtke has eight Arco Solar 16-2000 PVs and solar hot air collectors.

The author's home with twelve Siemens SP-75 modules.

Unique to Jon's home, the solar-electric system supplied all the energy for the construction of the building. Many residents of Stelle helped with the "wall raising" on a very hot August day about four years ago. This beautiful home on a five acre farmette recently became fully operational using solar power, even though the grid is available. A total of 840 watts of PV, a Trace SW4024, and eight Concorde PVX-12210s power the entire house, including the Sun Frost refrigerator.

Simple technical descriptions of these earth-friendly power supplies hardly do justice to the way of life created in Stelle. A common observation of visitors is that we have a very special community. Indeed, it is a feeling of true community which is often lost in the urban sprawl.

After I'd lived for only six months in Stelle, there was not one neighbor who I would have hesitated to ask for help. In Stelle, you confront your issues—there is no place to hide. You know your neighbors and they know you. That may be perceived as good or bad. I think there should be a premium charged for being able to experience this kind of quality of life.

**A Community Perspective**

Stelle was founded in 1973 in a rural setting about sixty miles (97 km) southwest of Chicago. The Stelle Group, a philosophical organization chartered as an Illinois not-for-profit corporation, created Stelle. The Stelle Group set out to create a supportive environment in which individual human development would be top priority.

During the early years of building Stelle, when it was a private

Renie Emery and Kermit Wagoner have sixteen Arco Solar 16-2000 PV panels.

Mark and Vicki Matthews have twenty-eight Siemens SP-75s.

Today, Stelle is an open community where people from diverse backgrounds make their home. The values mentioned previously seem to serve as an unspoken beacon, which tends to attract new residents and maintain the ties with those who move away. Individual initiative and creativity are welcomed, and no single organization oversees all aspects of community life. Instead, different groups play various roles in the community.

community, residents stressed values such as personal responsibility, lifelong education, positive attitude, cooperation, and democracy. These values continue to influence the way of life in Stelle. As elements of its rich and unique heritage, they remain a vital part of the community's identity.

Richard Kieninger was the founder of Stelle, and author of the book *The Ultimate Frontier.* As he grew philosophically distant from the community he had founded, he moved a core group of followers down to Texas in the early '80s. Those who remained were more mainstream idealists. They re-created Stelle without forgetting the foundations of self reliance, and the goals of sustainablility. This re-creation was a natural step in the evolution of the community.

Dianne Obernuefermann has eight SP-75 and four SP-36 PV modules.

**Cooperation**

Stelle is self-governing, and an elected board of directors of the Stelle Community Association (SCA, a homeowners association) administers community affairs. The SCA operates on democratic principles and encourages all members of the community to become involved. Today, Stelle is a small and peaceful village of roughly 110 people.

Unlike many intentional or alternative communities, Stelle is based on cooperative, rather than communal principles. Residents live in the type of housing they prefer and can afford, and work at their own jobs or businesses according to their individual talents.

Some residents commute over an hour to downtown Chicago, while many operate businesses out of their homes. It is this background of diversity and strong individualism that supports the other activities that Stelle residents enjoy. Hobbies that include Tai Chi, canning, gardening, herbology, quilting, etc. seem to emerge from an underlying mutual respect for nature and the environment.

One demonstration of this respect is that Stelle is the smallest community to receive the Tree City Award from the National Arbor Day Foundation. We have just been chosen again for the year 2000, which makes fifteen years of receiving this honor. Tree City USA promotes tree planting and care programs, and calls public attention to the economic, health, and aesthetic benefits trees offer. The program encourages participation in community forestation and beautification efforts.

Combine the rural location of Stelle and the associated challenges of

Paul and Karen Wagoner have eight roof-mounted Siemens SR-100s and twenty-four SM-55s on a tracker.

being thirty miles (48 km) from the nearest supermarket with the earth consciousness of most Stelle residents. This gives you a community that is embracing self reliance. A winter storm can keep residents cut off for over a week at a time. Power has gone down for several days at a time regularly over the years. This aspect of rural life combined with new Illinois solar incentive money—and a new solar-friendly perspective by Commonwealth Edison—has caused a new wave of solar activity in this tried and true community.

**Share the Dream**

On the drawing board is something tentatively named "The Midwest Center for Sustainable Living." The Stelle Area Chamber of Commerce hopes to facilitate a more formal and productive way for Stelle to share its sustainable attributes with a broader audience by construction of this center. Several universities and other key groups are involved in the initial phase of this effort, which includes obtaining a grant from the newly established Clean Energy Trust Fund.

A business plan is being developed to make the center self-supporting with corporate eco-retreats, personal growth seminars, holistic health seminars, sustainability think tanks, and, of course, wind and PV technical training, etc. Incidentally, Stelle has served as home to Midwest Renewable Energy Association (MREA) wind/PV hybrid workshops, and hopes to further this effort. The goal will be to demonstrate new energy technologies in a real end-of-grid support scenario, which will offer an added dimension to college-level classroom learning.

**Visit Stelle**

You are encouraged to visit Stelle. The residents open their doors every spring to celebrate Earth Day, and every fall to participate in the National Tour of Solar Homes. If these dates aren't convenient, someone is always available for a personal tour of the town. Tuesdays and Fridays are best, and a call ahead of time is most appreciated.

For more information, or to see the town in person, call the special line SunWize has set up for Stelle visitor inquiries (815-256-2224). We will be happy to fax directions, and we strongly advise you not venture on your own without a map. Visitors come from all over the world to see solar technology at work in Stelle.

Tim and Susan Wilhelm have twelve Siemens SM55s.

**Access**

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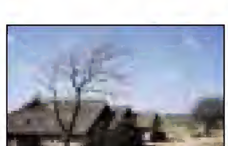
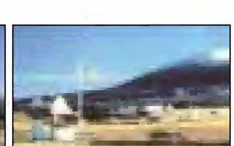


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It could take five to ten years for comparably rated monocrystalline modules to generate the electricity equal to that used in their production. Note: Computer simulation showing comparably rated monocrystalline system and its frame.

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# Home Power's 24 Volt System

**Richard Perez and Joe Schwartz**



**Every renewable energy system seems to grow over time. With our system, the growth was steady over the years. As we continually added more computer equipment to produce *Home Power*, our electrical energy needs grew. So we'd just add more modules to the system to supply the additional electricity we needed. Well, eventually Ohm's Law caught up with us.**

### The Way It Was—*Home Power's* 12 Volt System

A corollary of Ohm's Law states that power is equal to voltage times current. For any given amount of power, twice the current is required at 12 volts compared to 24 volts. We were already moving tremendous amounts of current at 12 volts to supply our needs.

I remember glancing at the ammeter that measures PV current input to the system and seeing 242 amperes due to edge-of-cloud effect one morning. Our arrays would commonly deliver a steady 160+ amperes into the system. There was just no way we could expand this system further without replacing the six pairs of #1/0 (53 $mm^2$) copper cable connecting the PVs (76 modules in all, divided into six arrays) to the power room. The time had come to upgrade our system to a higher voltage, and reduce the amount of current we were moving.

**Sub-array #1: Sixteen BP-590 PV panels on a dual-axis Wattsun tracker provide 1,140 rated watts at 24 VDC.**

Before making this upgrade, we were the largest 12 volt system we have ever heard of. We were cycling between 10 and 13 KWH daily at 12 volts. About 75 percent of this energy was consumed by the computer equipment in our office, and 25 percent by our home appliances. A daily use of 10 KWH is far beyond what a 12 volt system should cycle. The general rule of thumb is that systems cycling more than 2 to 3 kilowatt-hours daily should move to a base system voltage of 24 VDC or higher.

Please realize that this is the story of a system that supplies both a home and a business. The system is also used for testing RE equipment. As a business system, some energy conservation choices open to homes are not available. We cannot defer chores until the sun comes out. We need consistent and high quality power, so the system is overbuilt compared even to a typical large home system.

Many all-AC RE homes of this size might move up to 48 volts. We didn't do this because 24 VDC is a very common RE system voltage, and we want to be able to test the gear most systems use. Also, the more series elements in a battery bank, the more vulnerable it is to a single cell failure.

### Making Changes—Choices, Choices, Choices

We already had a huge amount of RE equipment. Our job was to design the 24 volt system so that much of the equipment already in our 12 volt system could be reused. We began with a survey of our PV modules. To produce 24 volts, two 12 volt modules need to be connected in series. For maximum output, it is essential that these two series-connected modules be identical—the same make, model, and age.

**In the power room, the battery box provides a raised floor for equipment access.**

**Sub-array #2: Eight Kyocera J51 PV panels on a Zomeworks tracker provide 408 watts rated.**

Our arrays had many individual modules that had no identical partner. So it was apparent to us from the very beginning of this upgrade that we would also need our 12 volt system if we wanted to use these "odd man out" PVs. Keeping our 12 volt system meant that we could directly supply our 12 VDC appliances, and apportion our loads between the 12 volt and 24 volt systems.

It also allows us to continue to test 12 VDC RE gear. The 12 VDC system was fully operational during the upgrade. The 24 VDC system went on line in September 1999. The PVs are apportioned about 60 percent 24 volt and about 40 percent 12 volt, but we will probably move some more over to the 24 volt system in the future.

We also needed more energy storage, so we decided to buy a new battery bank for the 24 volt system. We could reuse our PV controls, but since inverters are voltage specific, we needed new inverters. A combination of the new battery and new inverters ran us out of our existing power room—there just wasn't space for all this new gear. Our old power room was located in a three by ten foot room scabbed onto the side of our house. Many folks have bigger closets than this. We decided to move the power room to another location. These projects have a way of snowballing…

**New Power Room**

We built the new power room off the east end of *HP's* straw bale bathhouse (see *HP63 & 64).* The power room currently houses the 24 VDC system, and the 12 VDC system will soon live there as well. The location is central to both the editorial office/residence and the power production sources. With the exception of the wind genny, all system loads and power sources—including the PVs and the engine generator—are within 100 feet (30 m) of the new power room.

Because of the sloping grade of the building site, the east wall of the bathhouse is 14 feet (4.3 m) high from ground level to the eaves. We used this height to our advantage and laid the power room out in two levels. A built-in battery box provides the base for the upper level, which is at the same height as the bathhouse floor. Here there's access to all power processing hardware: inverters, power centers, and charge controllers. Four steps take you down to ground level where the electronics workbench, testing equipment, and a Windoze computer for data logging are located. (Analog to digital conversion hardware for the Macintosh is expensive, and rare as hen's teeth.)

The building is south-facing and well insulated, with R-19 insulation in the walls and R-30 in the floor and ceiling. Without any supplementary space heating, the indoor temperature rarely drops below 50°F (10°C). The building is conventional stick frame. The floor is beefed up with 6 by 8 inch beams (15 x 20 cm) to support the weight of the batteries. There is a door directly into the bathhouse from the upper level, and an exterior door down below.

**Sub-array #3: Eight more Kyocera J-51 PV panels, ground mounted.**

### The 24 Volt System—The Nickel Tour

The 24 VDC system currently powers approximately 75 percent of *Home Power's* total electrical load. All loads are AC (except the Wattsun tracker controller and the Power Vent, which run battery-direct). All of *HP's* computers and office equipment are powered by the 24 VDC system. In addition, lighting and appliances in the bathhouse, circulation pumps for the solar thermal system, and the cabin of Mix Master Dave (ace *HP* stucco mixer and DJ) are all powered by this system.

A "1" in the "Priority" column in the load table means that the load is assumed to either be operational or that it can automatically activate itself (for example, a refrigerator). This field is used for inverter sizing. Adding up the priority wattages allows us to size the inverter so that it is never overloaded. Overloading the inverter will cause it to shut off, thereby blacking-out the system.

PV output is run through a power center where fused disconnects are provided for each of the three 24 VDC sub-arrays. Two charge controllers regulate the PV output. A 24 VDC 1,750 ampere-hour battery bank serves as storage for the system. The DC energy stored in the batteries is inverted to 120 VAC by two inverters, and then distributed to the office and household loads. With this basic layout in mind, let's take a look at the specifics of each leg of the system.

### Energy Sources—the Good, the Bad…

The 24 VDC PV array consists of 32 modules and is configured into three sub-arrays. The rated output of the total array is 1,840 watts. If we derate this figure by 15 percent, it better reflects real-world PV operating temperatures and outputs. The actual output of the PV array is about 1,560 watts, or 65 amps at 24 VDC. We regularly see 65 amps on the PV output meter. Each

**Home Power's 24 VDC System—Energy Consumption**

| *Qty.* | *Inverter-Powered Appliances* | *P* | *Run Watts* | *Start Watts* | *Hours /Day* | *Days /Week* | *W-hrs/day* | *%* |
|---|---|---|---|---|---|---|---|---|
| 1 | Sony 24 inch color monitor | 1 | 150 | 300 | 9.00 | 7.00 | 1350.0 | 17.28% |
| 2 | Grundfos solar DHW pumps | 1 | 75 | 75 | 8.00 | 7.00 | 1200.0 | 15.36% |
| 1 | Radius 20 inch color monitor | 1 | 80 | 200 | 8.00 | 7.00 | 640.0 | 8.19% |
| 1 | PowerComputing computer | 1 | 60 | 120 | 9.00 | 7.00 | 540.0 | 6.91% |
| 1 | Macintosh G3 computer | 1 | 60 | 120 | 8.00 | 7.00 | 480.0 | 6.14% |
| 2 | APS 2 GB hard drives | 1 | 30 | 50 | 8.00 | 7.00 | 480.0 | 6.14% |
| 1 | HP Laserjet 4M laser printer | 1 | 780 | 1000 | 0.50 | 7.00 | 390.0 | 4.99% |
| 1 | APS 18 GB hard drive | 1 | 35 | 70 | 9.00 | 7.00 | 315.0 | 4.03% |
| 4 | Compact fluorescent lights | 1 | 15 | 15 | 5.00 | 7.00 | 300.0 | 3.84% |
| 1 | 8 GB FWB RAID | 1 | 35 | 80 | 8.00 | 7.00 | 280.0 | 3.58% |
| 1 | Taco hydronic circulating pump | 1 | 30 | 30 | 8.00 | 7.00 | 240.0 | 3.07% |
| 1 | Sony CD player and Yamaha amp | 1 | 30 | 30 | 7.00 | 7.00 | 210.0 | 2.69% |
| 1 | Mitsubishi 19 inch television | 0 | 60 | 300 | 3.00 | 7.00 | 180.0 | 2.30% |
| 1 | HP Laserjet 4M printer, standby | 1 | 80 | 80 | 2.00 | 7.00 | 160.0 | 2.05% |
| 1 | Macintosh PowerBook G3 | 1 | 25 | 25 | 8.00 | 5.00 | 142.9 | 1.83% |
| 1 | Hitachi video cassette recorder | 0 | 40 | 40 | 3.00 | 7.00 | 120.0 | 1.54% |
| 1 | Casio cordless telephone | 1 | 5 | 5 | 24.00 | 7.00 | 120.0 | 1.54% |
| 1 | Panasonic fax, standby | 1 | 5 | 5 | 24.00 | 7.00 | 120.0 | 1.54% |
| 1 | Staber washing machine | 0 | 160 | 500 | 1.25 | 4.00 | 114.3 | 1.46% |
| 1 | Riccar vacuum cleaner | 0 | 1350 | 2700 | 0.50 | 1.00 | 96.4 | 1.23% |
| 1 | Maxoptix 5.2 GB magneto optical drive | 0 | 80 | 160 | 1.00 | 7.00 | 80.0 | 1.02% |
| 1 | UMAX color flatbed scanner | 0 | 120 | 250 | 4.00 | 1.00 | 68.6 | 0.88% |
| 1 | 3Com EtherNet LAN hub | 1 | 125 | 125 | 0.50 | 7.00 | 62.5 | 0.80% |
| 1 | Panasonic fax, operating | 1 | 150 | 150 | 0.50 | 5.00 | 53.6 | 0.69% |
| 1 | Miscellaneous power tools | 0 | 750 | 1500 | 0.20 | 2.00 | 42.9 | 0.55% |
| 1 | APS 640 MB magneto optical drive | 1 | 25 | 50 | 1.00 | 7.00 | 25.0 | 0.32% |
| 1 | Polaroid 35 mm slide scanner | 0 | 50 | 100 | 1.00 | 0.50 | 3.6 | 0.05% |
| | | | | | | *Total* | 7814.6 | |

**On the north side of the power room, the Honda generator provides 6,500 watts of backup power.**

sub-array is wired directly to the power center on discrete conductors. This allows us to use dedicated 100 mV/100 A shunts to monitor the output of each individual sub-array.

The heavy producer, 24 VDC sub-array #1, is the sixteen panel dual-axis Wattsun tracker we installed in September of 1998. We ran this array at 12 VDC before converting it to 24 VDC for the new system. The Wattsun is powered directly from the 24 VDC battery bank. Compared to array-direct operation, this configuration is ideal. The tracker orients toward the east after nightfall, eliminating morning wake-up problems.

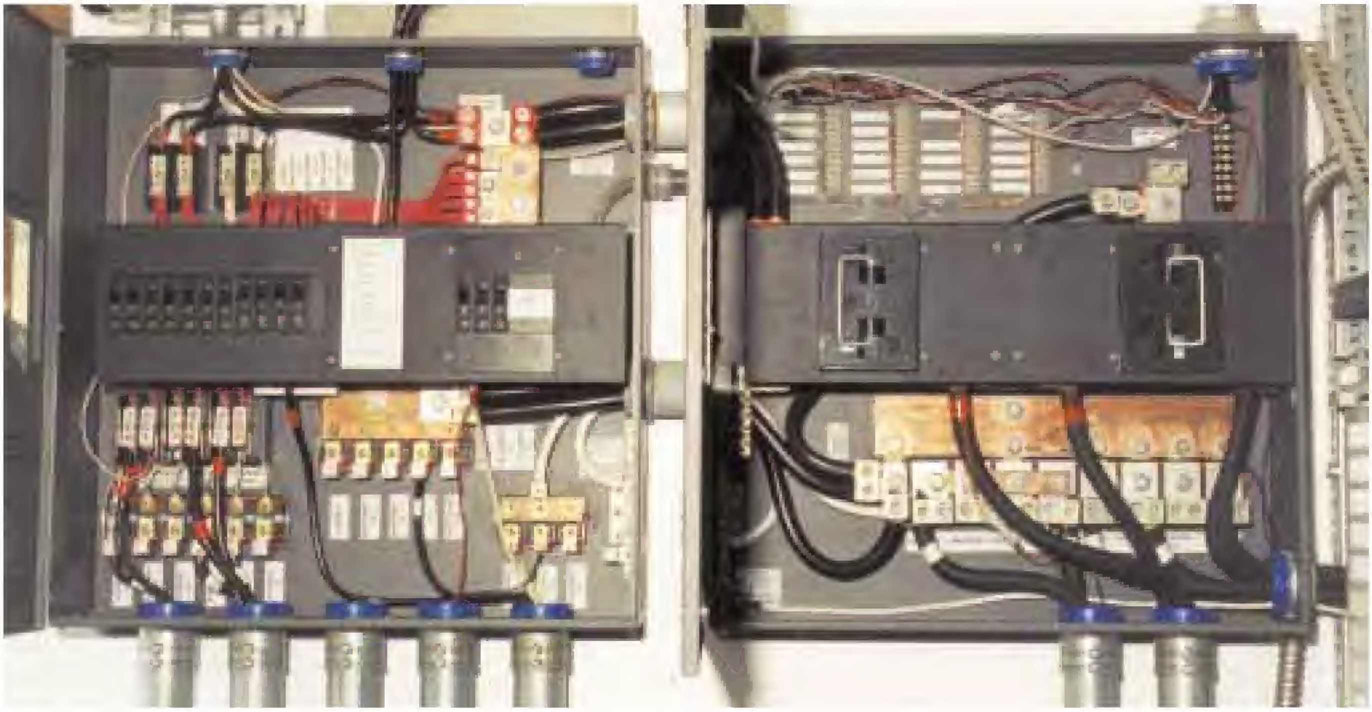
The tracker holds sixteen BP-590 modules rated at 90 W peak power each. These laser-grooved BP modules have a maximum power point of 4.86 A at 18.5 VDC. The high voltage of the modules is beneficial in locations with high ambient temperatures, because PV voltage drops as module temperature increases. High voltage PVs are also optimal when the PV output is run through a controller with maximum power point tracking (MPPT) capabilities, or through a linear current booster (LCB) in array-direct water pumping applications.

A Zomeworks tracker, installed in 1992, tracks 24 VDC sub-array #2. The Zomeworks holds eight Kyocera J-51 modules. The output of this array is 12 A at 24 VDC. Two four-module ground mounts hold an additional eight Kyocera J-51 modules and make up 24 VDC sub-array #3. The output of this array is also 12 A at 24 VDC. The ground mounts are adjusted for the sun's angle seasonally.

A 6.5 KW Honda ES6500 gas generator serves as a backup charging source during very cloudy weather. We've logged a total of 54.6 hours on the generator's elapsed time meter since the 24 VDC system came on line last September. This system is designed to operate the generator less than 200 hours yearly. One of the generator's 120 VAC legs, hot L1, is run through a Trace SW4024 to charge the 24 VDC battery bank. The generator's second 120 VAC leg, hot L2, is run through a Statpower PROsine 2.5 KW inverter to charge the 12 VDC battery bank.

This configuration keeps the generator balanced and allows for efficient charging while it is running. If the 12 VDC battery is full, L2 can be easily configured to provide AC power to two 75 amp Todd chargers. The Todds are wired in series for 24 VDC output, and provide an additional 60 amps to the 24 VDC battery when the battery voltage is low. L1 or L2 can also be used to run the 1/3 hp, 120 VAC well pump that keeps our two 1,350 gallon (5,110 l) storage tanks full of tasty mountain water.

**The Nerve Center: Two charge controllers (RV Power Products and Heliotrope), a double-wide Ananda Power Center, two Todd chargers, two 4,000 watt inverters (Exeltech and Trace), and plug-and-play AC distribution.**



**The custom Ananda power panel allows for multiple combinations of PV, wind, hydro, and generator power sources; controllers; inverters and DC loads; shunts for discrete metering; and future expansion too.**

**Controls—Keeping It Under…**
We are currently using two charge controllers in the 24 VDC system to regulate PV output. An RV Power Products Solar Boost 50 amp maximum power point tracking (MPPT) controller conditions and regulates the output of 24 VDC sub-array #1. The high voltage of the BP-590 modules, and the maximum power point tracking capability of the Solar Boost 50 *(Things that Work!* page 70) has proven to be an awesome combination.

We often see an 11.5 to 29.5 percent increase in controller output current compared to PV current into the controller. Since *Home Power's* system is cycled daily, we defeated the float mode of the Solar Boost 50, and set the bulk charge voltage at 29.6 VDC. With these settings, the 24 VDC battery receives overcharge amp-hours and micro-equalizations on a daily basis. Float mode makes sense in systems that are not cycled regularly. It also reduces battery gassing and watering.

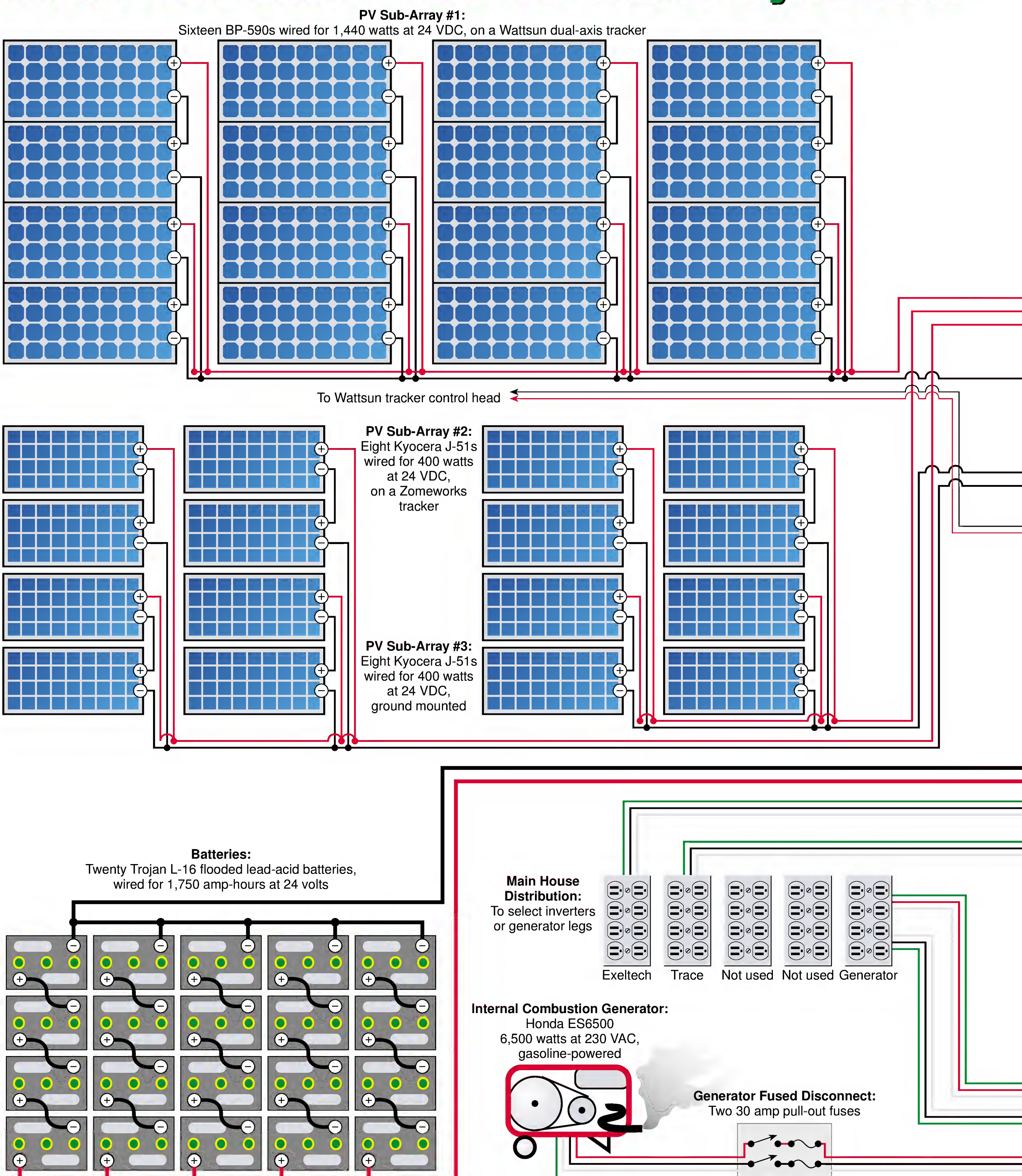
The 24 VDC system gets cycled to about 10 percent depth of discharge (DOD) each night. We still do routine, full-blown equalizing charges with the PV arrays at C/20 for five to seven hours every three months or every five deep cycles (to 50% DOD or greater), whichever comes first. This is super easy since both controllers have an equalize setting, and the Exeltech will operate at the elevated voltages that occur during equalizing charges.

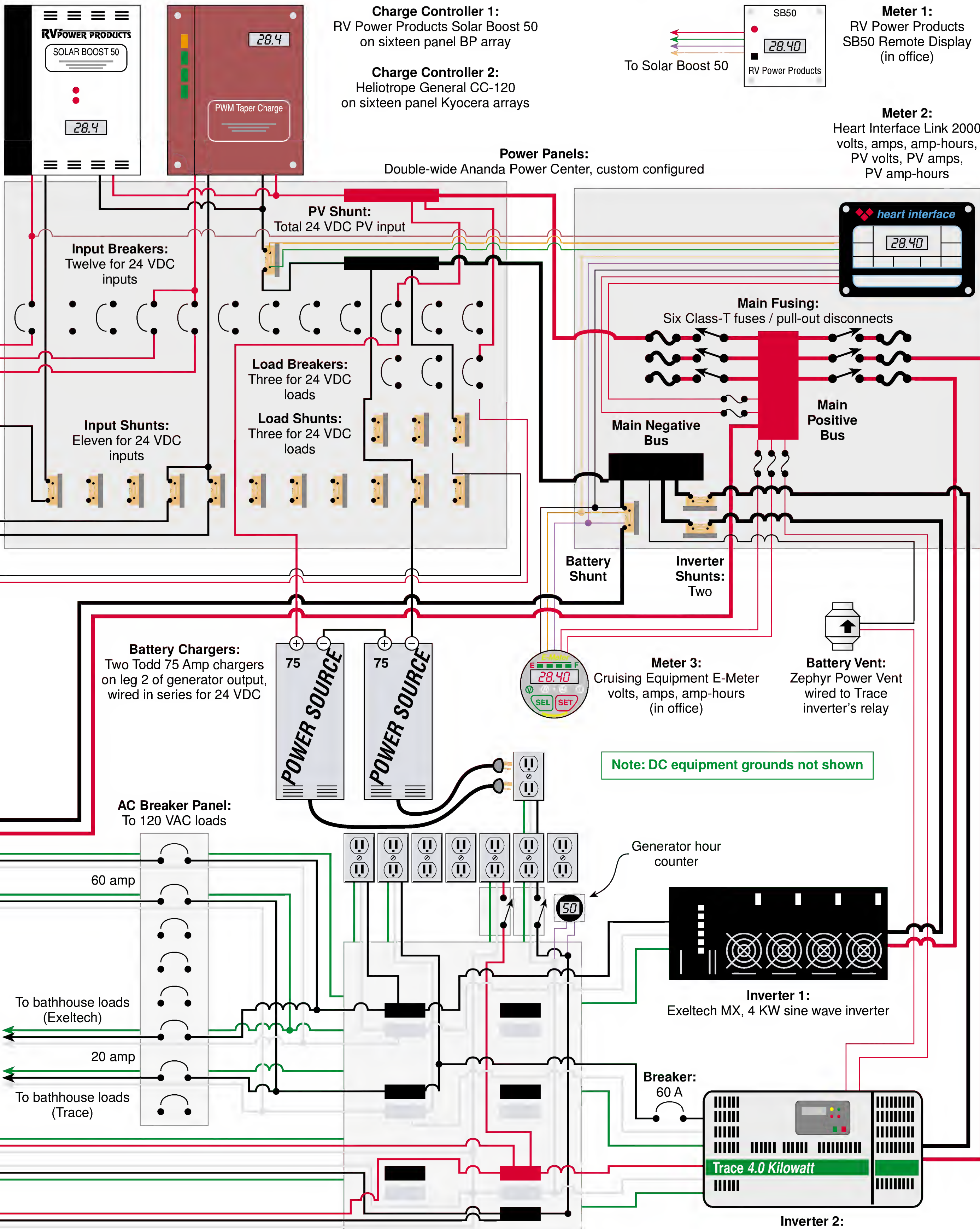
When we re-configured the sixteen Kyocera modules from 12 to 24 VDC, a Heliotrope CC-120 *(Things that Work! HP48,* page 36) was pulled from the 12 VDC system and incorporated into the 24 VDC system. The CC-120 is a long-proven performer and regulates 24 VDC sub-arrays #2 and #3. The controller has plenty of headroom for additional modules.

**The Power Center**
An Ananda Power Center serves as the DC wiring and fusing hub for *HP's* current 12 VDC system. While the power center seemed roomy at first, its input and output channels quickly became occupied. The power center was filled to the point where it was hard to get the cover closed! As a result, external terminals, fuse blocks, and breakers have been added over the years.

The space inside a power center is high-end real estate. Richard had this in mind when he designed a custom 24 VDC, double-wide power center for the folks at Ananda to build up. This is truly one sick piece of hardware. The left-hand panel of the new power center has twelve 24 VDC input channels. Included are source channels for six PV sub-arrays, one hydro turbine, two wind generators, two battery chargers, and a blank channel that's sure to be filled sooner rather than later. Three fused DC load channels are also provided. The right-hand panel has terminal blocks and Class-T fuses for three 24 VDC inverters, one 5 KW wind generator, and a shunt load output.

# Home Power's 24 Volt System





RV POWER PRODUCTS
SOLAR BOOST 50
28.4
PWM Taper Charge
Charge Controller 1:
RV Power Products Solar Boost 50
on sixteen panel BP array
Charge Controller 2:
Heliotrope General CC-120
on sixteen panel Kyocera arrays
SB50
28.40
RV Power Products
To Solar Boost 50
Meter 1:
RV Power Products
SB50 Remote Display
(in office)
Meter 2:
Heart Interface Link 2000
volts, amps, amp-hours,
PV volts, PV amps,
PV amp-hours
heart interface
Power Panels:
Double-wide Ananda Power Center, custom configured
PV Shunt:
Total 24 VDC PV input
Input Breakers:
Twelve for 24 VDC
inputs
Main Fusing:
Six Class-T fuses / pull-out disconnects
Load Breakers:
Three for 24 VDC
loads
Load Shunts:
Three for 24 VDC
loads
Input Shunts:
Eleven for 24 VDC
inputs
Main Negative
Bus
Main
Positive
Bus
Battery
Shunt
Inverter
Shunts:
Two
Battery Chargers:
Two Todd 75 Amp chargers
on leg 2 of generator output,
wired in series for 24 VDC
75
POWER SOURCE
Meter 3:
Cruising Equipment E-Meter
volts, amps, amp-hours
(in office)
SEL
SET
Battery Vent:
Zephyr Power Vent
wired to Trace
inverter's relay
Note: DC equipment grounds not shown
AC Breaker Panel:
To 120 VAC loads
60 amp
To bathhouse loads
(Exeltech)
20 amp
To bathhouse loads
(Trace)
Generator hour
counter
50
Inverter 1:
Exeltech MX, 4 KW sine wave inverter
Breaker:
60 A
Trace 4.0 Kilowatt
Inverter 2:
Trace SW4024, 4 KW sine wave inverter

**Inverters: An Exeltech MX 4 KW (top) and a Trace SW4024 4 KW (bottom).**

The power center is loaded with twenty-two shunts. Each DC input, output, and inverter channel has a dedicated shunt for data acquisition. Additional shunts allow for measuring a variety of total input and output currents. The layout of the power center gives us the ability to combine or separate individual source channels to test controllers over a wide range of ampacity ratings. The double-wide also allows ample room for rewiring as components undergoing testing are rotated through the system.

### Inverters

An Exeltech MX-series inverter and a Trace SW4024 *(Things that Work! HP48,* page 26) provide 120 VAC power from the 24 VDC battery. The Exeltech powers all of *Home Power's* office and computer equipment. We chose the MX based on Exeltech's reputation for building extremely durable inverters with exceptional AC power quality characteristics.

The MX series uses a rack-mount approach for modular inverter configuration. *Home Power's* MX utilizes a 19 inch (48 cm) cage to hold four individual 1,000 watt inverter power modules. Each individual module has a surge rating of 2,200 W, a peak efficiency of 89 percent, maximum total harmonic distortion (THD) of 2 percent, and produces true sine wave power. The power modules do not function as stand-alone inverters, but are controlled by either a control card or a master inverter module.

*HP's* MX uses two control cards to provide control signals to the individual modules and to synchronize their AC outputs. The two-card system offers redundancy. If one card fails, automatic transfer to the second card occurs. An additional alarm card has both an LED display and an audible alarm to signal that a control card has failed. The alarm card also displays DC on, AC on, load presence, module failure, AC breaker open, over temperature, and low input voltage. For large systems that demand uninterruptable, high quality power, the AC output characteristics of the Exeltech MX series are hard to beat.

We wanted to totally eliminate the possibility of dumping *HP's* computers during production due to motor load surge. (OK, call us paranoid, but after you lose one Quark or Freehand file that represents hours of labor by our editing, graphics, and layout crews, paranoia looks like a much better idea…) So we keep the office and computer loads separate from large inductive loads.

A Trace SW4024 is the workhorse inverter in *HP's* 24 VDC system. Trace's SW-series inverters are also the backbone of most residential RE systems worldwide.

**Twenty Trojan L-16s provide 1,750 amp-hours at 24 VDC.**

The AC distribution center provides test plugs for seven possible 120 VAC power sources.

The Trace SW4024 has a surge rating of 9,200 W, a peak efficiency of 94 percent, and maximum THD of 5 percent.

We use the Trace to power up large motor loads like the well pump, washing machine, and power tools. It has performed flawlessly. Unlike the MX series, the Trace SW4024 inverter does have an onboard AC battery charger. When PV output is low and the batteries require recharging from the engine generator, the SW4024's three-stage, 120 amp DC charger is just the ticket.

**Batteries**

*HP's* present 12 VDC battery bank is made up of four 820 ampere-hour Surrette 6-CS-25PS batteries, for a total of 1,640 AH at 12 VDC. We decided to run Trojan L-16 batteries in the 24 VDC system so we could compare the performance of the two battery makes side by side. Since both batteries are at the same temperature and receive about the same discharge and charge cycles, we will be able to assess battery efficiency and longevity. In the 24 VDC battery bank, twenty Trojan L-16s are wired into five series strings of 350 AH at 24 VDC each. These series strings are wired in parallel for a total battery capacity of 1,750 AH at 24 VDC.

We used #2/0 (67 mm$^2$) ExCELENE welding cable for the battery interconnect cables because of its flexibility and +105°C, 600 V insulation rating. The cables are fitted with heavy-duty lugs that are crimped, soldered, and sealed with shrink tubing. Custom making the cables only took a couple of hours. The result? The lug to cable connections are high quality (we know 'cause we built 'em!), and the overall cable length is 50 percent of factory-made cables.

Inside the AC distribution center are lugs for multiple AC sources. The 3-pole generator lug is at lower right.

We took care to make all the battery series and parallel cables exactly the same length. This means that the parallel electrical paths within the battery bank have equal resistance. A battery is a series/parallel array of electrochemical cells. Each cell has very low resistance, around 0.003 ohms. If the cables connecting the cells into a battery are dissimilar, it introduces more resistance in some of the elements of the battery than in others. Even small amounts of resistance are important here because the cells themselves have such a low resistance. Resistance differences in the cables can work some of the cells harder than others. It can also recharge some of the cells harder than others. The battery is more efficient and longer lived if all the cells share equally in the charge and discharge processes.

We replaced the factory L-16 battery caps with Water Miser battery caps. These caps have a flip top and allow watering of the batteries without removing the caps. The caps include a pellet medium for additional surface area inside of the cap. As the batteries gas, the pellets increase recombination, which in turn reduces battery watering. The caps are sturdy, well built, and designed to withstand high gas levels during equalization charges.

**System Metering—**
**The Eyes & Ears**

Good metering is an essential element in any battery-based RE system. For the nerds up at *HP*, hardly an hour goes by when we don't give the system meters a once over. And when the wind's blowing hard, or we're getting good edge-of-cloud effect on the PVs, it's a lot more frequent than that.

The 24 VDC system has meters in two locations. A Cruising Equipment Link 2000 provides system status information in the power room. Battery and 24 VDC sub-array #1 voltage, total PV current, net battery current, and battery amp-hour figures can all be accessed from this meter. The meter also displays historical data such as maximum amp-hour discharge. An LCD display on the Solar Boost 50 gives us battery voltage, and 24 VDC sub-array #1 input and output current figures. During product testing, a Fluke 43 and several Fluke 87 digital multimeters are used to gather system data.

Radio frequency (RF) interference from inverters, charge controllers, and loads can affect the accuracy of meter data. We ran twisted pair, shielded cable for all the meter wiring. Inside the power room, the meter wiring is also routed through EMT conduit. This further

**The battery box is super insulated and solar-hydronically heated.**

reduces the potential for RF interference.

Remote metering for the 24 VDC system is located in the office. Here a Cruising Equipment E-Meter and a Solar Boost 50 remote display give us system data. The 12 VDC system currently employs three amp-hour meters. Two TriMetric meters provide information on the stand-alone radio telephone power system. We're looking forward to getting one of the TriMetrics installed in the 24 VDC system soon. When there's one amp-hour meter in the system, it's god. When there are two meters, occasional discrepancies make you wonder. With three meters, measurements or inaccuracies can usually be verified without busting out the Flukes or data logging.

**Insulated battery box lids lift out for battery watering and maintenance access. Replaced, they act as a floor for access to power components on the walls.**

**Hydronically-Heated Battery Box**

The *NEC* requires a 36 inch (91 cm) working clearance in front of all hardware and disconnects. In most cases, this means that batteries can not be located directly under the inverter. As a result, long inverter/battery cables are a common compromise with large battery banks.

The box that houses *HP's* 24 VDC battery bank also serves as the floor for the upper level of the power room. This layout allows the batteries to be located directly under the power center and inverters, while maintaining spacious working clearance in front of the hardware. The multi-level setup has the advantage of keeping the batteries in close proximity to the inverters. This reduces battery to inverter cable lengths and the potential for voltage drop when the inverter is heavily loaded.

The battery box is an L-configuration and is framed with 2 by 4 inch studs and sheathed with 1 1/8 inch (2.9 cm) plywood. The top is plywood, with five panels fitted with recessed handles. On the 12 V side of the box, there are two 2 by 4 1/2 foot (61 x 137 cm) lids, and on the 24 V side, there are three 2 by 3 foot (61 x 92 cm) lids. By removing individual panels, all of the batteries can be conveniently accessed from above for watering and maintenance. Rubber mats keep dirt from finding its way between the access panels.

The top, sides, and bottom of the box are insulated with 2 inch, R-14.4 Mylar-backed rigid foam board. Two intake vents are located on the ground floor level. A Zephyr Industries Power Vent *(Things that Work!* page 76) is located in the upper rear corner of the box. The fan actively vents hydrogen gas to the outside when the batteries are charging and battery voltage rises above 27 VDC. The exhaust fan is controlled by one of the auxiliary relays in the Trace SW4024.

The new power room has no active space heating. This meant that, except for the building and battery box insulation, the batteries would live in an unconditioned space. Because lead-acid battery performance is directly proportional to battery temperature, this setup seemed less than ideal to us. While discussing this problem, Richard flashed on the idea of hydronically heating the battery box.

*Home Power's* domestic hot water is provided by two solar thermal collectors feeding two 50 gallon (189 l) tanks and a backup 35 gallon (132 l) propane-fired water heater. On most days, the 20 tube Thermomax and 10 by 4 foot (3 x 1.2 m) SunEarth flat plate collectors produce more hot water than we can use. We needed another load on the hot water system to help keep the collector temperatures reasonable. Because of its proximity to the hot water system, the battery box was the perfect candidate.

The battery box wall studs were drilled out, and 96 feet (29 m) of 1/2 inch (1.3 cm) diameter PEX tubing was snaked through them. The tubing was then plumbed into the DHW system. In some systems, this setup wouldn't be very practical, but in ours it makes perfect

**1/2 inch PEX tubing carries the hot water through the battery space. Intake for the Power Vent is visible above.**

sense. Except during the summer months, the hydronic loop in the battery box balances the hot water load and production almost perfectly. The propane-fired water heater rarely comes out of pilot.

A 0.5 amp, 120 VAC Taco pump circulates the water through the hydronic loop. We installed a Brand 20-1850 KWH meter on the pump, and were pleased to find that the pump only consumes an average of 64.7 watt-hours daily during the winter months. Good insulation—and the 2,500 pounds (1,134 kg) of thermal mass provided by the battery—are key factors in the hydronic system's success. With very little additional energy input, we've been able to control battery temperature within a range of 68 to 72°F (20–22°C), which is just about optimal for lead-acid batteries.

**Putting It All Together**

*Home Power's* RE system is not a typical residential system by any stretch of the imagination. In addition to supplying the power to produce the magazine and run the household loads, the system is used extensively for long-term testing of RE hardware.

Our first design criteria was to keep the system as modular as possible. This modular approach is present from start to finish. The PV sub-arrays are grouped in varying output increments with individual home runs. This allows us to test charge controllers of varying ampacity ratings.

All power processing components are mounted on 1.5 inch (3.8 cm) steel angle that we call "rack," since we use it to make mounting racks for PVs. The power processing equipment can be easily installed or removed. The rack leaves 1.5 inches (3.8 cm) of clearance from the wall, which increases the air circulation around the hardware, resulting in lower operating temperatures. All of the raceways and conduit used in the installation are oversized for ease of wiring, since system modifications take place on a regular basis.

We put together a custom 120 VAC distribution center to distribute power to the loads. This setup consists of six 600 V combiner blocks. Each inverter has a dedicated two-pole block for coupling inverter output with various loads or power distribution cables. A three-pole block distributes hot L1, hot L2, and neutral from the generator to the inverters, stand-alone AC chargers, or the well pump. A sixth combiner block is available for future modifications.

Bonded ground blocks are provided for conductor and equipment grounding. Dedicated single-gang receptacles installed on each combiner block are used to apply incremental loads to a given inverter during testing. A breaker panel located above the distribution box serves as overcurrent protection for each inverter, and for branch circuits within the power room and bathhouse.

Six pairs of #1/0 (53 mm$^2$) aluminum USE wire distribute AC power from the inverters and generator to the office and house. The conductors were sized to keep voltage drop below 3 percent, even under the full surge capacity of our largest inverter, the Trace SW4024. The output of each inverter has discrete conductors for flexibility and testing inductive loads in the office and house. Additional sub-panels provide overcurrent protection for office and house branch circuits.

**Plug and Play—System Flexibility**

For years, we had reveled in the convenience of the "power closet" attached to our home/office. We could plug virtually any circuit in the house or office into any one of three inverters. Since the largest inverter we had at that time was only 2.5 KW, it took managing the power to make sure we didn't overload any particular inverter.

We decided to keep this convenience even though the inverters would be located 100 feet (30 m) away in another building. All that was necessary was six pairs of wires from the new power house to the old power closet. Easy to say, but it was hard, and expensive, to install these #1/0 (53 $mm^2$) USE aluminium conductors. We used up the better part of two 1,000 foot spools of the stuff.

We installed five, four-gang receptacle boxes on these wires. We can now choose any one of four inverter channels or either leg of the generator to power various house, office, or other circuits. This comes in really handy for big jobs such as pumping water and running power tools. We can select either the 12 or 24 volt system depending on which system is energy rich at the time.

We can further select one of two inverters within that system depending on which is least occupied at the time. This degree of flexibility makes using both systems more efficient, and really comes in handy for testing new inverters. This setup is not necessarily suitable for most residential systems because it is arguably not code compliant.

**Are We Done Yet?**

By the time this issue of *Home Power* goes to the printer, the 12 VDC system will have joined the 24 VDC system in the new power room. All of the AC distribution for the 12 VDC system, as well as wire runs for remote, office-based system monitoring, are already in place. The layout of the 12 VDC system follows the same design parameters used in the 24 VDC system. Modularity again comes first and foremost. Also on the top of the power system "to-do list" is a new, PC-based data logging system.

**The Journey Is the Destination**

We know better than to say we've arrived at the final RE system setup for *Home Power.* Experience shows us that this probably isn't true. But at least this time we've built in modularity, and the ability to easily change components. And we've moved the system into palatial operating quarters, getting it out of that cramped closet. We have no illusions that we won't continue to grow the systems and make changes.

Joe thoroughly enjoyed wrenching this system, saying, "It was devious enough to be fun as hell." Look for an article detailing *HP's* 12 VDC system in our next issue, *HP78.* Many of you will find our design techniques and system implementation useful in your own systems. We are happy to communicate any further details of this system to *HP* readers. Just send us email, and we'll let you know what we know. Richard did the design, and Joe did the wrenching.

*Home Power's* 24 volt system is an overtime system designed to cope with regular watt-guzzling magazine deadlines. It is difficult for us to say exactly how much it would cost to replicate this system. Many of the components were purchased years ago. We estimate that you would have to spend around US$30,000 to make a comparable system. Not cheap, but when large amounts of power have to be pure and uninterruptable, and the nearest utility power is six miles away…

**Access**

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Fax: 505-881-7572 • sales@wattsun.com
www.wattsun.com • Wattsun PV tracker

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bogart@bogartengineering.com
www.bogartengineering.com • TriMetric AH meter

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Fax: 707-428-7878 • solarusa@bp.com
www.bpsolarex.com • PV modules

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Fax: 207-549-4568 • info@brandelectronics.com
www.brandelectronics.com • 120 VAC KWH meter

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www.exeltech.com • Inverter

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800-443-5853 or 425-356-5500 • Fax: 425-356-5116
fluke-info@tc.fluke.com • www.fluke.com • DMMs

Heliotrope PV, PO Box 1053, Fall Creek, OR 97438
541-937-9812 • Fax: 541-937-9813
rvsolar@continet.com • PV controller

Kyocera Solar Inc, 7812 East Acoma Dr., Scottsdale, AZ 85260 • 800-544-6466 or 480-948-8003
Fax: 480-4831-6431 • info@kyocerasolar.com
www.kyocerasolar.com • PV modules

Pulse Energy Systems (formerly Ananda Power Technologies), 870-E Gold Flat Rd., Nevada City, CA 95959 • 530-265-9771 • Fax: 530-265-9756
info@pulseenergy.com • www.pulseenergy.com
Power center

RV Power Products, 1058 Monterey Vista Way, Encinitas, CA 92024 • 800-493-7877 or 760-944-8882
Fax: 760-944-8882 • info@rvpowerproducts.com
www.rvpowerproducts.com • Solar Boost™ 50 charge controller

SunEarth, Inc., 4315 Santa Ana St., Ontario, CA 91761
909-605-5610 • Fax: 909-605-5613
info@sunearthinc.com • www.sunearthinc.com
Solar DHW collector

Surrette Battery Company Limited, PO Box 2020, Springhill, NS B0M 1X0 Canada • 800-681-9914 or 902-597-3767 • Fax: 902-597-8447
sales@surrette.com • www.surrette.com • Batteries

Taco Inc., 1160 Cranston St., Cranston, RI 02920
401-942-8000 • Fax: 401-942-2360
dongra@taco-hvac.com • www.taco-hvac.com
Hydronic circulating pump

Thermomax, 5560 Sterrett Pl., Columbia, MD 21044
800-7SOLAR7 or 410-997-0778 • Fax: 410-997-0779
info@thermomax.com • www.thermomax.com
Solar DHW collector

Todd Engineering, 28706 Holiday Pl., Elkhart, IN 46514
800-439-8633 or 219-293-8633 • Fax: 219-295-8527
dwilson@toddengineering.com
www.toddengineering.com • Battery chargers

Trace Engineering, 5916 195th St. NE, Arlington, WA 98223 • 360-435-8826 • Fax: 360-435-2229
inverters@traceengineering.com
www.traceengineering.com • Inverter

Trojan Battery Company, 12380 Clark St., Santa Fe Springs, CA 90670 • 800-423-6569 or 562-946-8381
Fax: 562-906-4033 • applications@trojanbattery.com
www.trojanbattery.com • Batteries

Zephyr Industries, Inc., PO Box 52, Salida, CO 81201
719-530-0718 • Fax: 719-539-7052
mail@zephyrvent.com • www.zephyrvent.com
Battery box vent

Zomeworks Corp., 1011 Sawmill Rd. NW, Albuquerque, NM 87104 • 800-279-6342 or 505-242-5354
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# Rural Solar in the Caribbean

## Monitoring Solar Home Systems in Bonaire, Netherlands Antilles

Mini Kroon and Margo Guda



Bonaire is a 112 square mile island in the Netherlands Antilles, 60 miles off the coast of Venezuela. It has about 13,000 inhabitants, of which 3,000 are retired Europeans and Americans. About twenty-five percent of the residents are rural and relatively poor—most of them farmers who hold other jobs as well. Twelve percent of the population is not served by the utility grid.

In close cooperation with Kriabon (a Bonaire farmers cooperative) and SEDE Antia (a development project granting organization), we have started a project with the aim of providing basic electricity needs for farmers in remote rural areas without grid connection. In all, this project involved fifty-five solar home systems. Twenty-five of them were installed in 1994. An additional thirty systems were installed in 1997, following the evaluation of the first twenty-five, which were considered to be a big success.

### Basic System

The systems were designed to provide enough electricity for five lights (one of which could stay on all night), use of either TV or radio for about three hours daily, and one pump to provide running water from an above-ground cistern close to the house.

The basic home system consists of two 60 Wp Solarex MSX-60 photovoltaic modules, a charge controller, one 165 AH lead-acid battery, a 48 watt DC pump, and a 250 watt Statpower Prowatt inverter so that standard TV and radio equipment could be used. The system also includes all DC cabling and module mounts. All systems were installed on the roofs, facing south. The final price of US$2,870 included design and installation.

Solarex USA supplied all the modules. The charge regulator, batteries, lights, and other materials were from GITT Holland BV. Kroon Procurement & Trading NV installed the systems. The owners, who had to be members of Kriabon, paid 25 percent of the system cost. The other 75 percent was funded by a grant from SEDE Antia.

**Because of Bonaire's tropical latitude, the Solarex MSX-60 PVs are mounted at a 15° angle from horizontal.**

**Monitoring the Systems**

Initial experience with the first twenty-five systems indicated a need for closely monitoring their use. Of special interest was the way people incorporated the new technology into their lives. Also, it was important to verify that the insolation estimates on which the system design was based—and the assumptions about the use of produced electricity—were essentially sound.

The monitoring project was partially sponsored by NOVEM, the Dutch government agency for energy and the environment. System owners maintained lists of hourly usage of the appliances and lights powered by the PV system. These lists were collected from the owners on a weekly basis. This weekly visit also served as a general maintenance and troubleshooting opportunity.

One important part of the monitoring project was an interview at the start of the monitoring period. In this interview, we asked users to help make an inventory of all equipment powered by their solar home system. We asked them to describe any additional equipment that they might have installed to supply extra power. We wanted to know how they felt about the new system, how it worked in their day-to-day lives, and whether they felt the energy the system yielded was sufficient for their needs.

**Avoiding Disappointment**

Most systems had already been used for over six months at this point. The interview therefore provided valuable information about questions and problems the owners had encountered. An introductory meeting, held before the systems were installed, had dealt extensively with the new technology and the way it is used. But many owners still had practical questions after six months of owning their system. Many were afraid to use the systems for the calculated hours. Other questions dealt with whether the energy would be sufficient to power additional equipment, such as kitchen appliances.

We stress these questions because many projects in other countries have run into problems with users overdischarging the batteries. The users of the system are usually unaware of the way the systems are designed, and once they get used to the convenience of the electric lights, radio, and especially television, they want the additional amenities they see on their television sets. If the limitations of the system are not made clear from the outset, disappointment is certain to enter into the equation at some point.

**How the Energy Is Used**

The table shows how different system owners used the energy from their systems. Overall, the biggest load was TV or radio. Lighting was the second largest load.

**Mrs. Beukeboom tests her new power system.**

Mrs. Mini Kroon installs one of the larger PV systems, with 6 Solarex MSX-60s.

Water pumping did not account for very much of the electrical energy use because water is a very expensive commodity in Bonaire, and people use it sparingly.

While exact insolation data was of course not obtained by this method, it was still possible to make a rough estimate. This was done based on the data for energy use combined with data for the time the battery would take to recharge. Battery recharging was usually complete sometime between 11 AM and 1 PM, after normal use the previous day and into the evening. These results suggest a yield higher than the design figure (5.5 hours at 1,000 W/m$^2$) for the annual average. However, the monitoring period did not include the rainy season, so the actual annual average will be lower.

There was a wide range of total energy used by different owners of home systems. It varied from a low of 151 WH per month for a home that is used part-time, to a high of 35,820 WH per month for a home that is not only permanently inhabited but where the owners work in the home. The homes with the highest energy consumption have additional PV modules installed on their systems. The basic solar home system does not provide enough energy for this relatively large demand.

**Keep It Simple**

The table lets you compare the energy end-use of various households in the program. Out of the 25 original systems, 19 are represented. Two owners did not want to cooperate, and others bought the systems for future use. While the system provides for the "basic needs" of electricity, each household clearly defines its basic needs very differently. One family may use most of its electrical energy to watch TV, while another family uses virtually the same amount to run a fan. It is important to decide on priorities!

Keeping the system small helps reduce the capital costs of the system, and provides energy services at a relatively low cost. In this way, PV is financially more attractive than grid connection for these rural households. The modular character of the home system makes increasing its size relatively trouble-free.

**Checkup**

Monitoring the use of the systems provided verification, in most cases, of the initial energy demand estimate. It also clarified, for most users, some important practical

**Kriabon Project Usage Monitoring**

| | *Average Monthly WH (Feb–Jun 1996)* | | | | | *Distribution* | |
|---|---|---|---|---|---|---|---|
| *Name* | *Lights* | *Radio/TV* | *Pump* | *Other* | *Total* | *Lights* | *Radio/TV* |
| P. de Meier | 24,990 | 3,940 | 6,563 | 0 | 35,493 | 70% | 11% |
| H. Rotteveel | 6,876 | 11,728 | 0 | 0 | 18,604 | 37% | 63% |
| E. de Palm | 901 | 15,796 | 0 | 0 | 16,697 | 5% | 95% |
| R. Strauss | 3,287 | 0 | 1,828 | 8,880 | 13,995 | 23% | 0% |
| J. de Palm | 3,328 | 7,728 | 670 | 0 | 11,726 | 28% | 66% |
| E. Emerenciana | 822 | 9,528 | 0 | 0 | 10,350 | 8% | 92% |
| M. Boezem | 1,644 | 6,415 | 0 | 0 | 8,059 | 20% | 80% |
| R.Emerenciana | 5,357 | 2,646 | 0 | 0 | 8,003 | 67% | 33% |
| E. Beukeboom | 769 | 5,936 | 739 | 0 | 7,444 | 10% | 80% |
| C. Winklaar | 4,927 | 0 | 0 | 0 | 4,927 | 100% | 0% |
| J. Clarinda | 4,577 | 13 | 0 | 0 | 4,590 | 100% | 0% |
| M. George | 1,008 | 1,648 | 434 | 0 | 3,090 | 33% | 53% |
| E. L. Silié | 586 | 187 | 0 | 0 | 773 | 76% | 24% |
| J. Frans | 250 | 69 | 131 | 13 | 463 | 54% | 15% |
| E. Manuela | 357 | 55 | 0 | 0 | 412 | 87% | 13% |
| E. Paula | 377 | 0 | 0 | 0 | 377 | 100% | 0% |
| J. Emerenciana | 163 | 163 | 43 | 0 | 369 | 44% | 44% |
| I. Coffi | 208 | 0 | 0 | 0 | 208 | 100% | 0% |
| N. Oleana | 151 | 0 | 0 | 0 | 151 | 100% | 0% |
| *Average* | 3,188 | 3,466 | 548 | 468 | 7,670 | 42% | 45% |
| *Average distribution of end use* | | | | | | 56% | 35% |

issues regarding the use of their energy systems. These included the importance of providing good waste heat disposal for the battery, and the value of a good battery maintenance.

We had to explain how a battery works within the system, and explain that the total energy available is determined by the modules, not the batteries. Many of the system owners thought that they could install more batteries and then have more energy to use. They didn't realize that the installed modules cannot supply more energy than 7 amps in full sun, or about 38.5 amp-hours per day.

Monitoring also provided an opportunity to fine-tune maintenance and troubleshooting. It provided verification of the maintenance schedule necessary for the system. This primarily concerns the standard flooded lead-acid batteries, which have generally been maintenance-free during the six months of the monitoring program. Only four batteries (out of a total of 25) needed water added. Just as a solar-electric system performance is site specific, the necessary maintenance routines are too.

**Dust & Salt**

The issue of dust and saline deposits proved, in some cases, to be much worse than expected. Bonaire is a small arid island with high relative humidity. The presence of dust and salt spray in the air is virtually universal. Because of this, we installed the panels low on the roofs, but still out of easy reach of thieves.

While specific conditions will of course differ from island to island, there are nearby islands with similar conditions, such as Aruba and Curaçao in the south Caribbean, and Antigua in the north. On these islands, PV modules will probably need more intensive maintenance than on islands with more rainfall and a less arid character.

Of course this is very site specific, depending on such items as traffic (most roads in the area are dirt), topography influencing wind flow patterns, soil conditions immediately upwind, and proximity to the ocean and salt spray. This could cause large differences between modules situated as little as 100 meters apart.

A good maintenance schedule for a solar home system in these conditions will call for cleaning dust and saline deposits from the PV modules every two to three months. On most other islands, and even at sites on these islands with less ambient salt spray, natural cleaning by wind or rain will probably make this effort unnecessary.

**Charge controller from GITT BV in Holland.**

**Know the Limitations**

Instructing the users (most often the owners) of the solar-electric system about its limitations and maintenance is crucial. It will take time, and the users will have the opportunity to become familiar with their systems. Careful, well-instructed users will get optimal energy services for the estimated lifetime of the systems.

Care should be taken to instruct these people well, preferably in their own language, and in such a way that the knowledge has a chance to become assimilated. Knowledge of basic electricity laws, maintenance guidelines, and safety precautions should never be assumed. Only by ascertaining that the technology is really transferred to its recipients can solar energy—and indeed renewable energy in general—be successful. It appears that one evening of information with slides and a question and answer session is insufficient for answering all the practical questions about this new technology.

**A Delco, 165 amp-hour, 12 volt lead-acid battery.**

Follow-up at later stages is necessary. Most people involved do not understand how a PV system works, or have even a minimal knowledge of the principles of electricity involved. They may have some practical experience with batteries because they have occasionally used car batteries for lighting in the home. But the components of even a basic PV system are completely unfamiliar to them. This would suggest more of a "black box" packaged-system approach. But due to cost, we did not have this option.

The system owners did not have much experience with RE systems. In addition to this barrier, language was a problem. At the outset of the project, the supplier spoke Dutch, while most of the clients had very little Dutch and no English. They speak the Antilles national language, Papiamentu. All technical informational materials were offered in English only, providing a triple barrier. The monitoring project, which involved one Papiamentu speaker in several question and answer sessions with the system owners, provided an effective way of overcoming these barriers.

**Simple Solar Works in the Caribbean**
The simple solar-electric rural home system provides a good way to implement solar energy for off-grid applications in the Caribbean. User education is critical to make these systems work. Because the annual average peak sun hours per day is high, the yield of even a small system can be comparatively high. Combined with energy efficient equipment, small photovoltaic systems can easily meet the electricity demand of an average rural family in Bonaire.

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Trace

full page

four color on negatives

this is page 55

# Little House on the Internet

## Accessing Today's Technology from a Remote Location

Alan Gross & Jane Townsend


**Covered water pipes (left) lead to the island house from the Southeast.**

When we moved from the island of Manhattan to the small Caribbean island of Bonaire (pop. 15,000), we thought we were going about as far as possible from the hectic life we knew in New York City. But after a couple of years in a pleasant residential neighborhood overlooking the sea, we realized that we had just traded urban America for suburban Caribbean, and that was not quite enough. Thus began our project to combine our love for our new island and its people with our desire to get further away from it all and "back to nature."

But could two former city dwellers really make the necessary changes for living off the grid? We were realistic enough to know that we were not willing to give up the luxuries that we had worked so hard to achieve. Could we do it without creating too much work for ourselves during our retirement years? Our electrical and plumbing experience before this project amounted to flipping switches and turning on faucets.

**Authors with the completed array on the carport roof.**

### Finding Our Own Sunspot

The first step was to find the perfect location for a remote home—good wind, views, and privacy. Wind would be very important because it is the ideal air conditioner for this environment. While the temperature is a fairly constant 85°F (29°C) with high humidity, the strong trade winds keep it comfortable most of the time.

Our land search turned into a two year adventure. In the end, several old and new friends formed an association to purchase 305 hectares (750 acres) of remote, rolling land on the windy and uninhabited east side of the island. The group agreed that the prime goal of the development was to preserve forever the natural beauty of the land.

We spent a long time drafting the 40-some restrictions that ultimately became a permanent part of the deeds. The two dozen lots are large, about 12 hectares or 30 acres each, but each owner can actually use only 1/3 of the land. No major trees or cactus can be destroyed, and no clear-cutting is allowed. Lots can never be subdivided, and only two houses can be built on each 30 acre lot. About 50 acres is held in common as parklands and roads.

In addition to struggling with Dutch law (Bonaire is part of the Netherlands Antilles), we had to learn about dirt-road building, aerial and land surveying, and land development. In the process, we discovered how to protect and preserve the land, and how to prevent run-off and erosion. We also learned about siting a home to capitalize on the natural advantages of the location without destroying it.

The "butterfly" roof collects water in the center, and drains it down the end columns for storage until needed.

**So Far, So Good**

Once we had the site, we had to determine how anyone could possibly live there, since it is several miles from the local utilities. Water was the primary consideration. Bonaire is a desert island with far more evaporation than the 22 inch (56 cm) average annual rainfall. It has little potable ground water, and no running streams. Could two people with four large dogs, a cat, and frequent visitors survive on six cubic meters (1,600 gallons) of water trucked in every two weeks, or was there a way to capture enough of the limited rainfall?

Tying in to the power grid would be impractical and, frankly, not even desirable. The island system is a hodgepodge of more-or-less 250/127-volt, 50 cycle electricity that will regularly fry sensitive electronic equipment. Other issues included the harsh elements: salt air, high winds off the sea, and intense UV exposure, since Bonaire is only 12.5 degrees off the equator. We needed to find materials and equipment that would withstand the elements with minimal effort from us.

Minimal effort was a key point since we were, after all, retired. We had no desire to be constantly painting and repairing, and we are not what you would call do-it-yourselfers. We would rather curl up with a good book than work out with a hammer and paint brush. So we had a lot of learning to do.

**Speeding the Learning Curve**

A borrowed copy of the Real Goods *Solar Living Sourcebook* got us going, and we found more education in several helpful texts. We even attended a short course at the Solar Living Center in Hopland, California. This two-day course went far toward eliminating our innate fears about energy self-reliance.

Shade/rain drop-down louvers, decks, and facia are recycled plastic lumber chosen for resistance to climate and insects.

Sub-arrays were assembled in the shade, then hoisted to the roof.

We then subscribed to *Solar Today* and *Home Power*. With this preparation, it was possible to start making some plans.

The information breakthrough came when the island got its own Internet provider. This gave us access to a world of information on every possible topic. We would no longer be limited to the one or two poorly stocked local stores for materials and supplies. With the Internet, we could shop the entire world to find what we needed. All of a sudden, the project seemed doable.

**An Active Approach to Passive Cooling**

Before designing the electrical system, however, we needed a house design. The primary criteria were energy efficiency, preserving the existing environment, lots of outdoor living, and the ability to collect rainwater without gutters that could clog up. Unfortunately, most books we bought focused on solar design for cold climates. Fortunately, the architect we found in Curaçao, Dito Abbad, of PLAN'D2, knew the climate well and how to work with it. As a result, the house is a big wind-control machine that can find cool breezes no matter where they come from, and can also slow down the 30 to 40 mph (13–18 m/s) gusts that often blow through.

The house features a wide center hall clerestory to vent heat up and out, lots of louvered doors, windows, and walls to adjust to the conditions, and a butterfly-shaped roof for water collection without gutters. We extended the overhangs, and built shading structures to reduce the need for air conditioning (called "erko" here on the island—phonetic for the Papiamentu "airco"). With our house design settled, we went to work on the energy systems.

**Powerful Decisions**

Solar, wind, or a combo? We knew we could not live with the constant noise of a generator. The decision not to use wind was made after helping a friend lower and raise his wind generator a couple of times for maintenance. Not for us, we said. The maintenance required in our salty environment was a lot more than we were ready to commit to.

We started by cruising the obvious Web sites, but quickly found ourselves unable to make rational choices. The technical descriptions were puzzling for beginners. We got good advice from several sources, but found it hard to choose among them.

What we really needed was a "referee." Enter Johnny Weiss of Solar Energy International (SEI). We had purchased Johnny's videotape on solar energy, along with several others on a variety of subjects. We were

Twenty-four Siemens SP-75 PVs provide 1,800 watts.

impressed with his down-to-earth approach, so we contacted him at SEI via email. Not only did he get back to us quickly (which, by the way, several others did not), he was instantly helpful, providing guidance and answers to some of our basic (sometimes stupid) questions.

After a couple of months of email correspondence, we set up a consulting relationship, and even arranged for Johnny to be on hand for the installation. This last part wasn't too difficult, since he is a scuba diver, and Bonaire is one of the premier dive spots in the world. Our connection with Johnny and SEI has proven to be one of the best decisions of our entire process. His advice was always balanced. He offered choices instead of answers and, more importantly, had a rationale for his position. Even now, he's just an email away when we encounter problems.

**Shedding Some Light**

First off, we reviewed our electric bills for the past four years and were shocked to see how much electricity we consumed—an average of about 50 KWH per day! Was this possible? We double-checked and, yes, it was real. Of course we used electricity for cooking, and we had a swimming pool pump running every day of the year.

Next, using one of the worksheets we came across, we developed a spreadsheet divided into specific areas (kitchen, office, lighting, laundry, swimming pool, etc.). We approached each section with the goal of minimizing usage without depriving ourselves of essentials. These essentials included individual night reading locations, computer work, lap pool for exercise, full cooking capabilities, and a laundry facility with a dryer for the rainy season. We kept reminding ourselves that we had worked too hard before retirement, and did not want to struggle at this phase of our lives.

Among the easy choices early on were to switch from electric cooking to propane, change from halogen and incandescent lamps to compact fluorescents (CFLs) for lighting, eliminate the laser printer in favor of an ink-jet, use a portable music system, and trade in the electric ice cream maker for an in-freezer type. It turned out that all of these changes improved our lifestyle instead of hindering it. But we still came up with a figure of 12 KWH per day.

**Easing the Load**

Next, we seriously analyzed our lighting needs, and found that we were using multiple fixtures or bulbs when single lights could do the job. So we decided to have as many fixtures as we wanted, but to have each one individually switched. Instead of doing without, we would just have to remember to turn each light off when

**Two huge Yuasa HUP 2 volt lead-acid cells are lifted to the power room. Total battery capacity is 1,275 AH at 48 VDC.**

not in use. We put glass blocks in key areas for light penetration (without heat), and insisted on a switch for the TV and microwave to cut out phantom loads.

We then dug deeper into the specific use of various appliances and office tools, and worked out a better estimate of just how many hours per week they were really needed. This was progress, but it was still a heavy energy overhead. We decided to retire our two PowerMacs in favor of new PowerBook laptops for less energy consumption and more computing power. It not only helped the usage chart, but also freed us from the office.

By changing the 24 volt swimming pool pump and septic tank aerator to solar-direct, there was even more savings. These would do fine with about six hours of strong sun year-round. The swimming pool pump only needs to run about eight hours a day, and uses two 85 watt BP modules. We use one of those floating sanitizers (Floatron) to boost the chlorine power. The septic tank aerator will do the job running during the day only, on a 120 watt Kyocera PV panel. Our invisible dog-containment "fence" uses two 25 watt Unisolar modules.

**Dual Trace SW5548 inverters make mounting the power panel a group effort.**

Then came the realization that, if we were to use a diesel generator as a *backup* power source, we could tie certain tasks to the genny and drop their loads from the plan. So we bought a water-saving Asko washer and dryer (both 240 VAC). The plan is to use them once a week on the generator and top off the batteries at the same time. We will also be able to use the generator for power tools, or for future 240 VAC air conditioning if we need it for the two low-wind months of September and October.

We also went looking for a gas stove that required little electricity—no clock, and no glow plug, which uses a great deal of electricity to ignite the gas. After exhaustive searches for a stove with spark ignition, we thought we had found one. On the word of a salesperson, we made our purchase and were happy. When the stove arrived, we found that it had not one but three glow plugs. This was a major communication breakdown. Our advice is to get the manual for each appliance, and read it yourself before you purchase.

We've decided to live with the glow-plugs for now. Fortunately, we use the stovetop much more than the oven, broiler, or griddle. The top burners *do* have spark igniters. So far the stove has not been a major drain, and it looks as if we will be okay.

### Finally, A System Plan

With the painless changes to our load profile, we had a more realistic energy budget of 4 to 5 KWH per day, instead of the wasteful 50 we had started with. The system would still need to be a large one, because we did not want to be constantly upgrading in the future, with all the attendant shipping and importing hassles.

The result was a 1.8 KW solar-electric system with a 15 KW Kohler diesel generator backup. These are married to a Yuasa battery bank of twenty-four 2 volt tubular cells. The 1,275 AH capacity should provide five to seven days reserve in the rainy season. So far, we have had no problem living within these limits. Just a year ago it would have been unthinkable that we could have reduced our usage so much.

In fact, our current usage averages about 5.5 KWH per day (110 amp-hours at 48 V)—right on target. We have lived here for over six months, including all of our rainy season. On most days, our batteries have been completely topped up by the sun. This year was one of the wettest and cloudiest years in recent history. We really *needed* the generator only one time, but we use it weekly to exercise it.

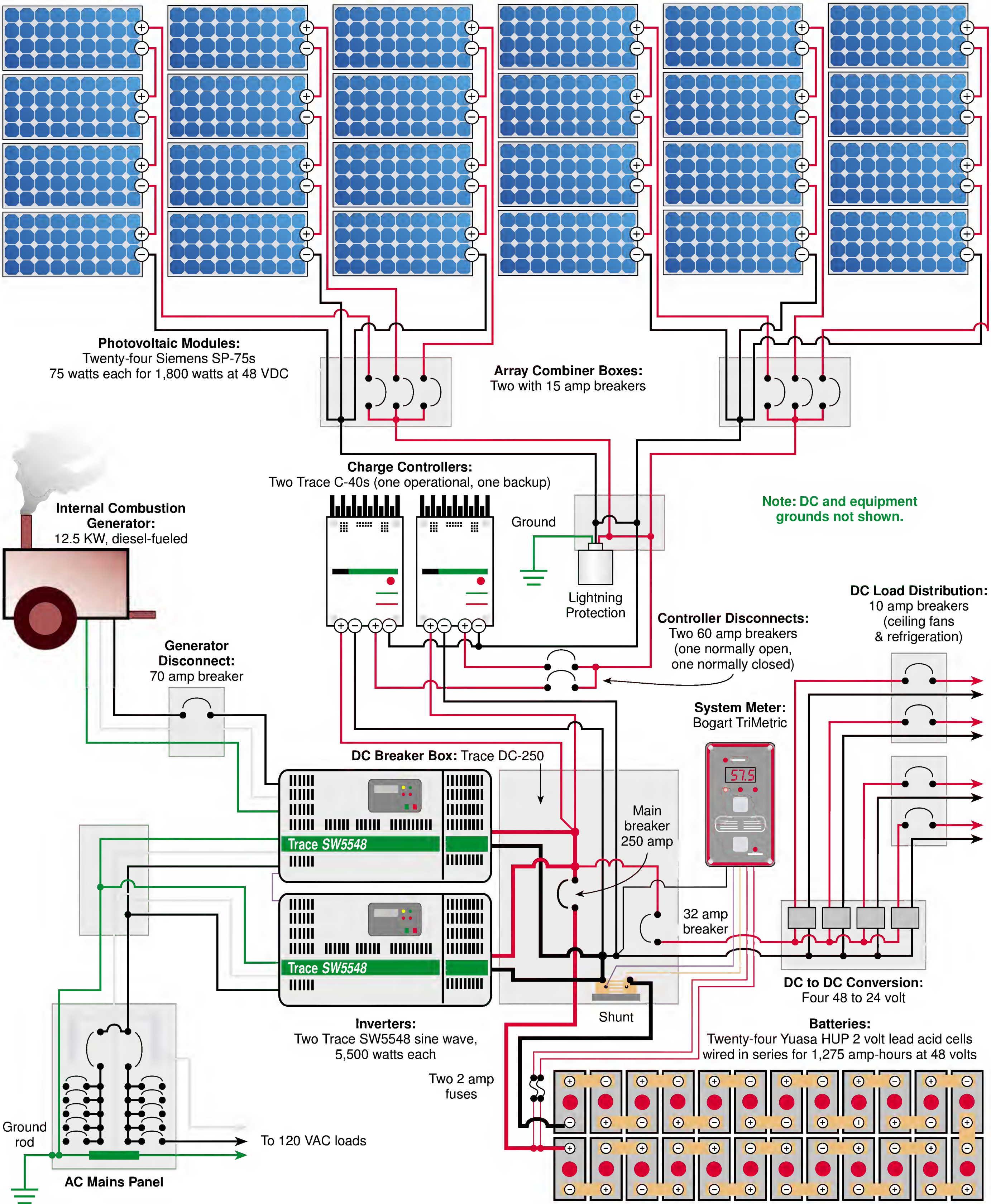
Once the type and size of the system was decided, it was time to work on the specific system components. Again, Johnny really proved his value. We were lost in a maze of controllers, inverters, circuit breakers, cables, and connectors ad nauseum. We jumped from one Web site to the next trying to make sense of all the elements. With Johnny's guidance, we were able to map out the proper components and ancillary parts so that when installation day arrived, everything was on hand.

### The Y2K Bug Bites

After four months of planning, it was time to place the orders. We started in December of 1998 with a planned shipping date of mid-May 1999. This would allow us to ship our container—which also carried our appliances, fixtures and lots of building materials—before the start of the hurricane season. Six months lead time should give us a nice cushion, right? Wrong!

We were among the few real victims of the Y2K problem, as orders for renewable energy components soared, and manufacturers went on back order. Lead

# Alan Gross & Jane Townsend's PV System



**Gross / Townsend System Loads**

| Qty. | | Watts | Hrs / Day | Days / Wk | Av. WH / Day |
|---|---|---|---|---|---|
| *Office* | | | | | |
| 2 | PowerBook computers | 45 | 2.0 | 3.0 | 77.1 |
| 1 | Epson printer | 86 | 2.0 | 3.0 | 74.1 |
| 1 | Tape drive | 75 | 0.5 | 1.0 | 5.4 |
| 1 | Hitachi monitor | 135 | 2.0 | 0.1 | 3.9 |
| 1 | Umax scanner | 300 | 0.1 | 0.1 | 0.4 |
| 1 | Polaroid scanner | 75 | 0.1 | 0.1 | 0.1 |
| | | | | *Office Total* | 161.0 |
| *Kitchen* | | | | | |
| 1 | Vestfrost freezer | 45 | 12.0 | 7.0 | 540.0 |
| 1 | Microwave | 1,700 | 0.2 | 4.0 | 194.3 |
| 1 | Asko dishwasher | 600 | 1.0 | 2.0 | 171.4 |
| 1 | Food processor | 400 | 0.1 | 0.5 | 2.9 |
| 1 | Blender | 350 | 0.1 | 1.0 | 2.5 |
| 1 | Mixer | 120 | 0.3 | 0.5 | 2.1 |
| | | | | *Kitchen Total* | 913.2 |
| *Lighting* | | | | | |
| 2 | Bedroom | 20 | 2.0 | 7.0 | 80.0 |
| 12 | Assorted others | 13 | 0.5 | 7.0 | 78.0 |
| 8 | Kitchen | 11 | 0.3 | 7.0 | 26.4 |
| 3 | Laundry and workshop | 30 | 1.0 | 2.0 | 25.7 |
| 1 | Bathroom ceiling | 22 | 0.8 | 7.0 | 16.5 |
| 5 | Hall and patio | 13 | 0.2 | 7.0 | 10.8 |
| 1 | Kitchen (halogen) | 20 | 0.5 | 7.0 | 10.0 |
| 1 | Office | 13 | 2.0 | 2.0 | 7.4 |
| 1 | Pantry | 22 | 0.3 | 7.0 | 5.5 |
| 1 | Bedroom ceiling | 22 | 0.2 | 7.0 | 4.4 |
| 2 | Carport | 22 | 0.1 | 5.0 | 3.1 |
| 1 | Den | 13 | 0.2 | 5.0 | 1.9 |
| 2 | Storage room | 22 | 0.2 | 1.0 | 1.3 |
| | | | | *Lighting Total* | 271.0 |
| *Household* | | | | | |
| 1 | UV purifier | 30 | 24.0 | 7.0 | 102.9 |
| 1 | Security, kitchen | 420 | 0.1 | 7.0 | 42.0 |
| 5 | Security, windows | 420 | 0.1 | 2.0 | 30.0 |
| 2 | Tool chargers | 35 | 1.0 | 2.0 | 20.0 |
| | | | | *Household Total* | 194.9 |
| *Entertainment & Communications* | | | | | |
| 1 | Cell phone base | 25 | 24.0 | 7.0 | 600.0 |
| 1 | Fax | 120 | 1.0 | 7.0 | 120.0 |
| 1 | TV | 375 | 2.0 | 0.5 | 53.6 |
| 2 | Radio chargers | 40 | 1.5 | 2.0 | 34.3 |
| 1 | Stereo | 55 | 2.0 | 1.0 | 15.7 |
| 2 | VCR and DVD | 30 | 2.0 | 0.5 | 8.6 |
| | | | | *Entertainment/Communications Total* | 832.1 |
| | | | | *Total AC Watt-Hours Per Day* | 2,372.2 |
| *DC Device* | | | | | |
| 1 | Sun Frost RF16 24 V | 120 | 6.3 | 7.0 | 750.0 |
| 1 | Sun Frost R19 24 V | 63 | 9.1 | 7.0 | 574.6 |
| 7 | Ceiling fans 24 V | 20 | 1.0 | 3.0 | 60.0 |
| 1 | Solar Force 48 V pump | 15 | 3.0 | 7.0 | 45.0 |
| | | | | *Total DC Watt-Hours Per Day* | 1,429.6 |
| | | | | *Total AC and DC Watt-Hours Per Day* | 3,801.8 |

times were running through the summer at best. We had to make changes. How about a Vestfrost freezer instead of the Sun Frost we had planned on? Better decide today—there is only one left in stock. Panel prices seemed to change by the hour. What was the best buy per watt? Let's go with the SP-75s. Our Trace meter became a Bogart TriMetric.

On and on it went. Then we struck one of the reefs on the Internet Sea. Our appliance supplier, who we found on the Internet—and who had been paid fully in February for April shipment—suddenly disappeared. No more Web site, no answer via phone ("this mailbox is full") or email, and faxes wouldn't go through. They were bankrupt. Our stuff was gone. Fortunately, American Express covered the entire loss with their insurance program. We scrambled around and were able to replace all the missing items on very short notice—thanks to Abot Mills, a great appliance company in Miami.

Shipping dates slipped by two months, but finally the container arrived in early July. And there it sat for the next two months, with twelve expensive, pre-filled monster batteries all the way at the back. Would they be okay sitting in a solar-baked container for another two months until the house got closer to completion? "Nothing to do but wait and see," counseled Johnny via email.

Johnny arrived to supervise in mid-September with Steve Sloan, a contractor and diving buddy who came along to help. The house was not as far along as originally planned. The roofer, who was not found over the Internet but on a neighboring island, failed to show up. So we had to rush back to the computer to find a material that could be used for potable water, and could be applied by the existing work crew. Just two days before Johnny arrived, the roof surface was ready for mounting the panels.

### Unwelcome Insolation

What was planned as a supervisory role for Johnny and Steve quickly changed to sweaty hands-on installation, since the work crew was busy trying to finish the house before the start of the rainy season. While Bonaire is out of the hurricane belt, the Atlantic hurricanes do steal our trade winds during September and October. The entire installation was done under extremely uncomfortable conditions: 90-plus degrees with 85 percent humidity and little or no wind. Half a day in the intense equatorial sun left us all beat. How the builders worked for eight hours each day is a mystery.

Our paralleled Trace SW5548 inverters came pre-installed in the Power Panel System, which was good. But it was big and heavy, and had to be muscled up

several temporary steps to the battery room and then onto the wall. Twelve 250 pound (113 kg) two-cell battery modules had to make the same trip. Fortunately, the true character of the Bonaireans came to the fore as the house crew gladly provided the necessary muscle.

Craig Carni and the crew at Two Seas built a beautiful battery box that will keep the local lizards off the cables and keep the system clean. They also built custom aluminum roof racks, designed to stand up to the strong winds and salty air. They are in a fixed, low-slant position since Bonaire is so near the equator. With email, faxes, and cellular calls from the roof of the house (which was the only place the cellular phone would get a signal), we were able to have day-to-day installation discussions with Craig.

**Staying Connected**

Johnny and Steve had to leave before the installation was complete, but at least we had DC refrigeration, and the electrician knew the plan. However, we also had an unexplained voltage drop whenever a load was applied to the AC side. Emails flew among Johnny, Trace, and us until we got a clear reading on the problem. The manual, which was downloaded from the net to be sure it was the latest version, failed to make it clear that the pre-installed computer cable has to be removed before the parallel master-slave cable is installed. The Trace engineers explained this point, and the inverters were working properly within minutes.

The first week in the house delivered three terrifying electrical storms. These sent us back to the Internet once again, to learn about lightning protection. At one site, visitors could give specifics on their location and receive a risk assessment. After scoring 9.5 out of a possible 10 as high risk, we quickly tracked down some suppliers of the necessary equipment. Again it was responsiveness that led to our purchase decision. Roger Harney of Harger Lightning Protection provided so much information and help so quickly that we never even considered the other sources.

**Drinking, Bathing, & Swimming**

A well was not a realistic choice, since most groundwater here is brackish. So we opted for a water supply system consisting of collected rainwater and truck-delivered drinking water. The water purification system (filtration plus UV) was designed and built by Offshore Marine Laboratories of Fort Lauderdale, communicating via email and fax.

Windy Dankoff and his crew quickly solved pumping and pressure problems. The 48 volt Solar Force pump provides sufficient water for domestic use. The system gives us the ability to safely shift back and forth between truck water and the rain collection if necessary. We have been using about 1.75 cubic meters (470 gallons) of water per week. We had it trucked in until our rainwater tank started overflowing, and then switched to rainwater, which is all we have used since December.

**The muscle (and brains) behind the completed photovoltaic installation.**

But where to store all that rainwater? A big tank was necessary because almost all of Bonaire's rain falls in a two or three month season. A glass-lined tank would be preferred, but to bring a fifty ton capacity tank to the island was outrageously expensive. Back to the Internet. Lots of choices, but all of them had serious drawbacks, except a glass-impregnated modular tank system made in Japan by Bridgestone. Since it shipped flat and in sections, the cost was about the same as a locally constructed tank, but without the leaching, cracking, and pH problems of concrete.

Swimming pools are relatively new on Bonaire, and the local technique for building them is to make concrete block walls and plaster them inside. They usually leak. We wanted a poured concrete structure, but needed advice on the best way to seal the walls to assure easy maintenance. Our lap pool will use a Dankoff Solar 24

**Gross / Townsend System Costs**

| *Description* | *Cost (US$)* |
|---|---|
| Kohler generator, ROY 15 | 11,000 |
| 24 Siemens SP-75 modules | 9,576 |
| Trace Power Panel (dual) | 8,950 |
| 24 Yuasa tubular batteries, 2 V cells | 7,660 |
| Two Seas custom battery enclosure | 1,900 |
| Two Seas UNI-GR-12 roof rack | 1,300 |
| Miscellaneous cables, conduit, hardware | 1,000 |
| 4 DC/DC voltage converters, 48/24 | 636 |
| 240/120 VAC transformer | 350 |
| PolyPhaser DC 48 V lightning protector | 319 |
| 2 Trace #4/0 inverter cables | 318 |
| Trace parallel stacking interface | 292 |
| Bogart TriMetric meter | 230 |
| 3 Delta AC lightning arrestors, LA 302R | 138 |
| 2 R/T DC load center | 108 |
| 4 Square D DC breakers | 36 |
| *Total* | $43,813 |

VDC centrifugal pump. This pool pump is wired for solar direct, or it can be connected to the battery bank in case of extended cloud cover. So far, this has not been installed, since the swimming pool hasn't been finished yet. It has been too wet this year to allow the concrete to dry sufficiently to seal and paint.

On the Web, we found Victor deFontenay, who provided excellent suggestions for our pool. We thought he must have stayed up nights thinking about our problem, since his replies were always available first thing in the morning. Then we found out that Vic is located in Australia! We also found Conrad Nelson at a company called EnduroSeal. We wanted to be able to seal the concrete of the pool and house foundation. Conrad was also very responsive via email with advice, instructions, and speedy shipping.

**Getting Rid of Wastewater**

After considering a composting toilet, and deciding that we weren't ready for that, we planned a four-chambered septic tank. But this meant putting the effluent back into the ground. What little groundwater that exists here is precious, and we didn't want to pollute it with wastewater. To make the outflow a lot safer and to control odors, we decided to aerate the waste before returning it to the soil. This proved to be one of the most difficult research problems to solve.

We first started looking at "sewage systems" with the search engines. This didn't go very far since most of the pre-packaged systems are highly energy dependent and designed for larger needs. Next we looked at aquarium, pond, and aquaculture systems, but still without success.

Finally, Windy Dankoff put us in contact with Jim Keeton of Keeton Aqua. Jim's company specializes in aquaculture, but he has been playing with the idea of getting into the sewage aeration business. This concept was so new that we never even saw a plan until the finished product arrived in Johnny's luggage. It's a solar-direct air compressor forcing air through a large diffusing stone. The diffusing stone (which creates billions of bubbles of air) sits in the third chamber of the septic system. The air pump is mounted in a plastic box on the outside of the septic tank. To insulate it, we built a small pump house around the plastic box. This seems to limit the noise, and still allows for enough cooling of the pump.

**Lumber & Non-Lumber**

Remembering that our goal for living with nature during our retirement years was to keep everything simple and not labor-intensive, we decided to use recycled plastic lumber for much of the decking and non-concrete needs. On the Net, we found U.S. Plastic Lumber, and Phoenix Recycled Plastic Lumber. Unfortunately, all the plans for our house were in metric scale and designed for standard timber. First we had to convert metric to English scale. Then we had to recalculate the lumber needs to allow for more supports, since the plastic lumber is more flexible than real lumber, and needs 12 inch centers instead of 16 inch.

After hours of agonizing conversions, we finally were able to place the order. Recycled plastic lumber is ideal, not only for its lack of maintenance in a salty, humid environment, but also because we are living on land originally owned by termites. Surprisingly, it looks very "natural" in this environment.

For the windows and doors, we needed a termite-resistant hardwood that was responsibly harvested. Via the Web, we could research wood properties, colors, and suppliers. We downloaded hundreds of pages of exotic information, and finally made a decision. The lumber we chose (Iroko) was purchased from a "green" source in Holland. And it is exactly what we expected it to be from the photos and descriptions on the Net. We also found a wood sealant via the Internet (Sealodeck), which met the specifications of low labor with high protection from UV, water, and salty air.

So we wouldn't have to keep painting our cement block construction every year (perhaps we are just lazy), we decided to use an acrylic stucco finish (Duroplex from Triarch Industries). This is a color-impregnated material that goes on like plaster but has the strength of light

steel. It should provide years of low-maintenance wear in this rugged environment.

Instead of traditional gypsum board ceilings, we found HardiSoffit which is a pressed cement-fiber product. This should hold up better against rain, high humidity, and insects. It was discovered while surfing the net for cement sealants. Who knew the product even existed? It certainly was not available on this small island, so we had to find a supplier (again, via the Internet) who could ship it down.

We bought stainless steel screws from Swan Secure via the net, some stainless steel legs to support the kitchen cabinets from a kitchen fabricator (Bellama) in California, stainless steel sink faucets from Grohe in Europe, a special, commercial aluminum shelving system from Italmacelli in Italy, and a retractable glass and aluminum "wall" from Henderson in England. All metal items had to be either stainless steel or aluminum because of the salty environment. Most of the hardware (hinges, door handles, etc.) came from Holland, since Bonaire has regular shipments from there.

We also learned how to build an electrified farm fence to keep local livestock away from our trees. We bought an electric fencing system via email from Kencove Fencing. It uses a Parmak fence charger, which is powered by a small built-in PV panel. Light fixtures from California and New York, and special small CFL bulbs from Springlamp in Ohio were all available to us, thanks to the World Wide Web.

The telephone/fax/Internet access problem has not yet been solved. We have been trying a Motorola fx 2500 (TDMA) which was designed for offshore locations. Unfortunately, the signal is not clean enough for digital transmission, and we can neither fax nor log on to the Net. So for now we make our Net connections when we are in town. If you have ideas or suggestions about remote telecommunications, we'd love to hear from you.

**The Internet is Energy Efficient**

As we sit on our patio watching the ocean pound Bonaire's windward shore, we wonder why a project that appeared so daunting at first seems so simple now. The answer is the Internet. We were able to find the information, people, and products we needed. And once we overcame the initial fear, we even had the nerve to try a number of innovative building techniques and products. Most have worked out well. We're glad we are living in an energy-efficient, environment-sparing home which is not labor intensive and does not require great sacrifices.

Even in this remote part of the world, it is possible to access the best technologies and some of the most helpful people who deal with these technologies. It seems that the same qualities we appreciate in making face-to-face purchases also can be accessed on the Internet—personal attention, responsiveness, honesty, and reliability.

Unfortunately, the same potential problems exist on the Internet as well—inflated promises, lack of follow-through, bad products, and rude treatment. Strangely enough, it seems no harder to choose good suppliers electronically than in person. In fact, since everything has to be reduced to writing, a lot of the hype falls by the wayside, or is more easily spotted.

Of course, the project was more than we bargained for. But we have learned a lot about the technology, and about the people who make it work. Given a choice, we'd do it again in just about the same way. And it was today's technology that made it possible for us to "get back to nature."

**Access**

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Willits, CA 95490 • 800-227-9523 or 707-459-9523
Fax: 707-459-1833 • sales @2seas.com
www.2seas.com • Battery box and panel rack

Technical Consumer Products Inc., 300 Lena Dr.,
Aurora, OH 44202 • 800-342-1496 or 330-995-6111
Fax: 330-995-6188 • sales@springlamp.com
www.springlamp.com • Compact fluorescents

RCH Fanworks, 2173 Rocky Creek Rd., Colville, WA 99114 • 800-529-6306 or 509-685-0535 Fax: 509-684-5199 • info@fanworks.com www.fanworks.com • DC fans

Charles Kendall, Kencove Farm Fence, 344 Kendall Rd., Blairsville, PA 15717 • 800-KENCOVE or 724-459-8991 • Fax: 724-459-9148 electricfence@kencove.com • www.kencove.com Electric fencing

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Kohler Power Systems, Kohler, WI 53044 800-544-2444 or 920-565-3381 • Fax: 920-459-1646 www.kohlergenerators.com • Generator

Trace Engineering, 5916 195th NE, Arlington, WA 98223 • 360-435-8826 • Fax: 360-435-2229 inverters@traceengineering.com www.traceengineering.com • Inverters

Roger Harney, Harger Lightning Protection, 301 Ziegler Dr., Grayslake, IL 60030 • 800-842-7437 or 847-548-8700 • Fax: 847-548-2292 sales@harger.com • www.harger.com • Lightning protection

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Victory deFontenay, deFontenay Pool & Fountain Design Consultancy • vic@pool-information.com www.pool-information.com • Pool information & consulting

Windy Dankoff, Dankoff Solar Products, 2810 Industrial Road, Sante Fe, NM 87505 • 505-473-3800 Fax: 505-473-3830 • pumps@danksolar.com www.danksolar.com • Water pumps

Andre Kramer, Offshore Marine Labs, 2200 S. Federal Hwy, Ft. Lauderdale, FL 33316 • 877-MAKE-H20 or 954-524-5433 • Fax: 954-524-8909 makeh2o@aol.com • www.offshore-marine.com Water purification

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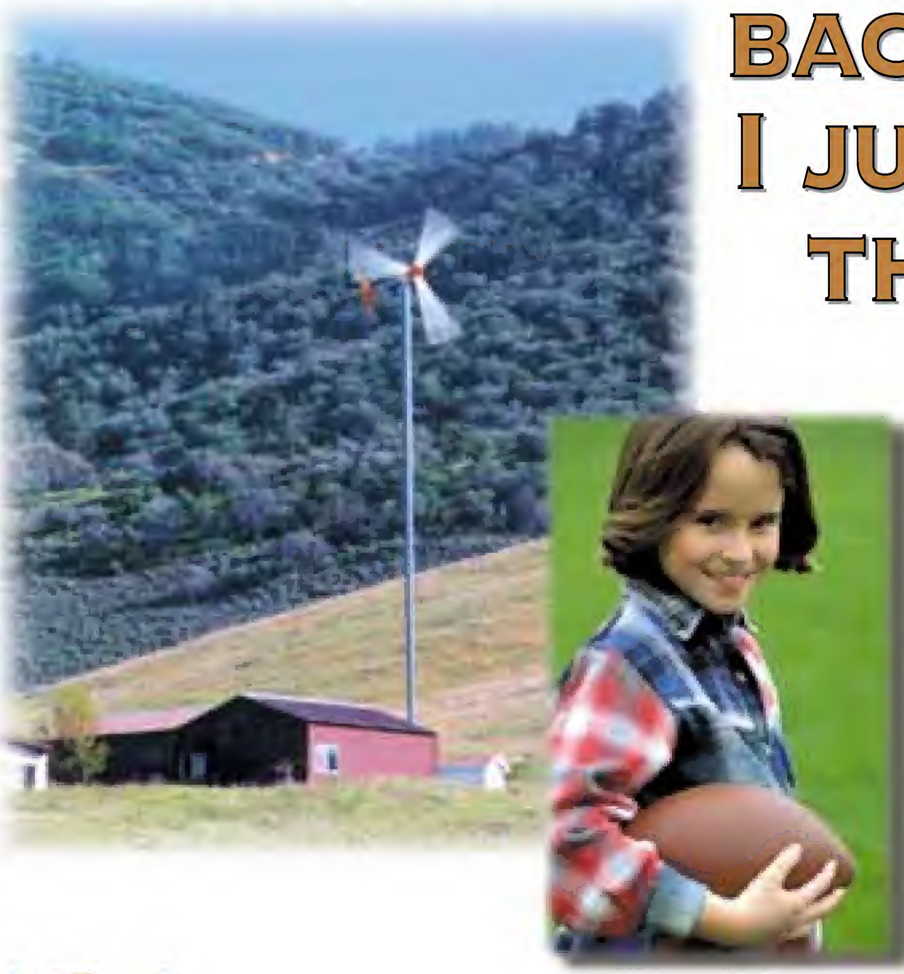

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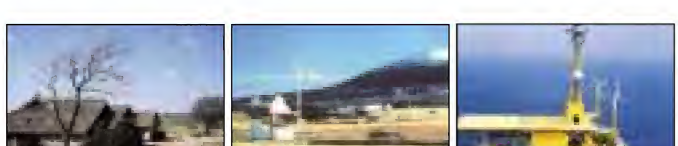

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Things That Work

*Tested by Home Power*

# RV Power Products' Solar Boost™ 50 MPPT PV Charge Controller

Tested by Richard Perez & Joe Schwartz



How would you like to get 10 to 30 percent more energy out of your PV modules? This maximum power point tracking (MPPT) charge controller will do just that!

**What Is Maximum Power Point Tracking?**
A maximum power point tracker is similar to the transmission in an automobile. They both couple a power source to a load more effectively and efficiently. What a car's transmission does mechanically, MPPT does electrically.

All PV modules have what is known as a maximum power point. The maximum power point is where module voltage times output current equals maximum power. A PV's maximum power point is constantly changing with module temperature and solar insolation. The MPPT controller tracks that power point as it changes.

In most PVs, the maximum power point at 25°C (77°F) is at 16.5 VDC or higher, while a typical battery bank is in the 12 to 15 V range. This overhead voltage or "voltage overkill" is built into PV modules by their manufacturers to compensate for voltage loss when the modules are hot. Heating a module can cause voltage depression of over 2.5 VDC just from a 25 to 50°C (77–122°F) temperature change. Batteries also change in voltage. A fully depleted 12 volt battery will have a voltage of about 12.5 VDC while under charge. A fully recharged battery will be about 15 VDC while under charge. (These figures assume a C/20 to C/10 rate of charge. Battery temperature and age are also factors). Both voltages are well below a PV's maximum power point.

The net effect is that PV modules spend most of their lifetime not operating at their maximum power point. There is more power to be had from the module, but we can't get at it because battery voltage, and thereby system voltage, is different from the voltage at which the PV module gives its maximum power.

The MPPT solves this problem by allowing the PV module, or PV array, to operate at its maximum power point regardless of battery voltage or module temperature. This little bit of electronic wizardry can enable a PV array to produce between 10 and 30 percent more power than it does without the MPPT. Day after day, this adds up to more energy for the system.

**Documentation & Shipping**
Lately we've received a heap of poorly packaged products damaged in shipping. We're happy to report that the Solar Boost 50 (SB50) was well packaged and arrived in fine shape. The manual is detailed, complete, and relatively easy to follow. It is eighteen pages long and contains wiring diagrams, tables, and more than enough illustrations.

**Solar Boost 50 Features & Programming**
The Solar Boost 50 model we tested, which includes a digital display, retails at US$469 and has a 36 month warranty. A model without a digital display is also available, and retails at US$389. The controller is field selectable for either 12 or 24 VDC operation. A 48 VDC model is in the works, but not yet available. The SB50 has a rated output of 50 amps at either 12 or 24 VDC.

An optional remote LCD display is available for US$109. This display is the SB50's best advertisement. It shows battery voltage, PV current into the controller, and current out of the controller. We often switch between the two current settings and walk away thinking, "man, it's like having another two modules!" Battery temperature sensors are also available for US$28.

While the Solar Boost 50's maximum power point tracking capabilities are awesome, it's also a well designed three-stage, pulse width modulated (PWM) charge controller. The Solar Boost 50 uses MOSFET transistors for efficient PWM regulation. Bulk, acceptance, and float mode set points are potentiometer based, and are fully adjustable for regulation up to 32 VDC.

For systems that are cycled on a daily basis, the float mode can be disabled, making overcharge amp-hours available to the battery. A manually initiated equalization mode is also provided. The controller is reverse-polarity protected and features an automatic current limit of 50 amps. This eliminates the nuisance tripping of breakers due to current spikes caused by edge-of-cloud effect on PV arrays.

The overall dimensions of the Solar Boost 50 are 10 by 9 by 3.5 inches (25 x 23 x 9 cm). A heat sink runs the entire height of the controller. Even at maximum output, you can comfortably keep your hand on the controller's heat sink. This is a simple indicator that the controller is running efficiently and is well designed thermally.

**Installing the Solar Boost 50**

*Home Power's* Solar Boost 50 regulates the output of sixteen BP-590 PV modules mounted on a Wattsun dual-axis tracker. BP-590s have a high peak voltage of 18.5 VDC, and are an excellent module for power point tracking. The array's 40 amp output consistently pushed the SB50's output up to its rated 50 amps.

Transmission line loss should be kept to a minimum because the SB50 uses overhead voltage to increase power into the batteries. The output of our BP array is

**Solar Boost 50 Data Sheet**

| *Outside Temp* | *Solar Insolation* | *PV Voltage* | *Battery Voltage* | *Input Current* | *Output Current* | *Amps Boost* | *Watts Boost* | *% Amps Boost* | *Watts In* | *Watts Out* | *Eff %* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 46.8 | 0.27 | 34.40 | 25.65 | 12.2 | 15.8 | 3.6 | 92.3 | 29.5% | 419.7 | 405.3 | 96.6% |
| 55.7 | 0.24 | 33.25 | 25.30 | 8.4 | 10.8 | 2.4 | 60.7 | 28.6% | 279.3 | 273.2 | 97.8% |
| 52.6 | 0.22 | 34.10 | 25.75 | 8.0 | 9.9 | 1.9 | 48.9 | 23.8% | 272.8 | 254.9 | 93.4% |
| 61.3 | 1.05 | 32.60 | 25.45 | 39.6 | 49.0 | 9.4 | 239.2 | 23.7% | 1291.0 | 1247.1 | 96.6% |
| 52.8 | 0.48 | 34.10 | 26.95 | 17.9 | 21.9 | 4.0 | 107.8 | 22.3% | 610.4 | 590.2 | 96.7% |
| 61.7 | 1.01 | 32.55 | 25.40 | 40.0 | 48.0 | 8.0 | 203.2 | 20.0% | 1302.0 | 1219.2 | 93.6% |
| 42.5 | 0.75 | 33.35 | 27.65 | 28.4 | 33.6 | 5.2 | 143.8 | 18.3% | 947.1 | 929.0 | 98.1% |
| 54.6 | 0.96 | 31.10 | 25.60 | 36.2 | 42.7 | 6.5 | 166.4 | 18.0% | 1125.8 | 1093.1 | 97.1% |
| 47.3 | 1.17 | 35.95 | 29.60 | 31.0 | 36.2 | 5.2 | 153.9 | 16.8% | 1114.5 | 1071.5 | 96.1% |
| 52.3 | 0.80 | 32.45 | 27.75 | 13.6 | 15.8 | 2.2 | 61.1 | 16.2% | 441.3 | 438.5 | 99.3% |
| 46.3 | 0.03 | 32.95 | 28.15 | 23.1 | 26.8 | 3.7 | 104.2 | 16.0% | 761.1 | 754.4 | 99.1% |
| 42.7 | 0.82 | 32.10 | 27.05 | 29.7 | 34.3 | 4.6 | 124.4 | 15.5% | 953.4 | 927.8 | 97.3% |
| 43.2 | 0.88 | 32.05 | 27.50 | 33.7 | 38.2 | 4.5 | 123.8 | 13.4% | 1080.1 | 1050.5 | 97.3% |
| 46.9 | 1.08 | 32.15 | 27.70 | 40.4 | 45.6 | 5.2 | 144.0 | 12.9% | 1298.9 | 1263.1 | 97.2% |
| 39.9 | 0.89 | 31.95 | 27.60 | 33.5 | 37.8 | 4.3 | 118.7 | 12.8% | 1070.3 | 1043.3 | 97.5% |
| 48.7 | 0.86 | 32.05 | 29.00 | 31.4 | 34.2 | 2.8 | 81.2 | 8.9% | 1006.4 | 991.8 | 98.6% |
| 47.2 | 1.10 | 30.75 | 27.40 | 41.7 | 45.4 | 3.7 | 101.4 | 8.9% | 1282.3 | 1244.0 | 97.0% |
| 55.0 | 1.11 | 30.80 | 27.90 | 42.3 | 45.8 | 3.5 | 97.7 | 8.3% | 1302.8 | 1277.8 | 98.1% |
| 51.9 | 0.97 | 30.95 | 28.15 | 36.8 | 39.8 | 3.0 | 84.5 | 8.2% | 1139.0 | 1120.4 | 98.4% |
| 58.9 | 1.04 | 30.10 | 27.15 | 39.5 | 42.7 | 3.2 | 86.9 | 8.1% | 1189.0 | 1159.3 | 97.5% |
| 54.0 | 1.02 | 30.20 | 27.60 | 38.5 | 41.2 | 2.7 | 74.5 | 7.0% | 1162.7 | 1137.1 | 97.8% |
| 50.7 | 0.71 | 32.55 | 29.55 | 26.2 | 28.0 | 1.8 | 53.2 | 6.9% | 852.8 | 827.4 | 97.0% |
| | | | | | *Average* | 4.2 | 112.3 | 15.6% | 950.1 | 923.6 | 97.2% |
| | | | | | *Minimum* | 1.8 | 48.9 | 6.9% | 272.8 | 254.9 | 93.4% |
| | | | | | *Maximum* | 9.4 | 239.2 | 29.5% | 1302.8 | 1277.8 | 99.3% |

run through 90 feet (27 m) of #4/0 (107 $mm^2$) aluminum URD cable to the power room. The negative leg is routed through a 100 mV/100 A shunt for metering, and then to the Solar Boost 50. The positive input leg runs through a 60 amp Square D breaker and is terminated at the SB50. Output from the controller goes to the positive and negative buses in the Ananda power center.

The SB50 uses an internal shunt to measure the rate of controller output charge current. When regulated current falls below approximately 1.0 amps per 100 amp-hours of battery capacity, the controller goes into float mode. Most residential battery banks experience highly variable loads during charging, depending on what appliances are being operated. The SB50 is equipped with external battery shunt sense terminals. These terminals can be wired directly to the main battery shunt. In this configuration the controller "sees" the loads and uses net battery current, rather than controller output current, as a reference point for more precise regulation.

The Solar Boost 50 is well built and a pleasure to work with. It has a full enclosure that is conduit ready, with 1/2 inch and 1 inch knockouts. The input and output terminals and circuit board are solidly mounted. And the enclosure leaves plenty of room for wire wrestling during installation.

**Solar Boost 50 Performance**

We have been testing the Solar Boost 50 since September of 1999. During this time, we've seen current and power boosts in the range of 5 to 29.5 percent. We measured outside ambient temperature, solar insolation (with a Li-Cor SB200 pyranometer), PV array voltage, battery voltage, input current to the Solar Boost 50, and output current from the Solar Boost 50. The high operating voltage of the BP-590 modules provide optimal conditions for the SB50 MPPT. Typical boost may be slightly lower. The table shows the measured and derived data.

The Solar Boost 50 works best when the battery voltage is low and/or the PV modules are cold. Both of these conditions are more prevalent during the winter, when we need the solar energy the most. At high battery voltage, 29.60 VDC, we measured 16.8 percent current boost. At low battery voltage, 25.45 VDC, we measured 23.7 percent boost. Power boost during the entire test varied from a low of 48.9 watts to a high of 239.2 watts. Average power boost was 112.3 watts during the entire test.

Solar insolation is the instantaneous amount of solar power striking a surface. The reference standard is 1 KW/$m^2$, which is also called 1 sun. We took data on the Solar Boost in a variety of sunlight conditions, including times with much less than full sun (1 KW/$m^2$). At 0.22 KW/$m^2$, the Solar Boost increased array current by 23.8 percent, from 8.0 amperes to 9.9 amperes. Similar boosts of 22 to 29.5 percent were seen during solar isolations of 0.24 KW/$m^2$ to 0.48 KW/$m^2$.

The Solar Boost 50 is a very efficient charge controller. A clue to this is that it contains no cooling fan and barely gets warm when processing well over 1 kilowatt of power. We measured a high efficiency of 99.3 percent and a low efficiency of 93.4 percent, with an average efficiency of 97.2 percent during our test. Efficiency in percent is watts out divided by watts in times 100.

If you have an array with four or more modules, you will save money by using an MPPT controller. The Solar Boost 50 is the right choice if your array output is 20 amps or more. The smaller Solar Boost 2000 *(Things that Work! HP73,* page 70) is appropriate for smaller arrays. When doing cost comparisons, bear in mind that you are buying a quality PWM controller in addition to the MPPT capability. Direct comparison is not always easy, since the Solar Boost 50 is cheaper than some non-MPPT 50–60 amp controllers, and more expensive than others.

**Revolutionary**

Every so often a product comes along that significantly changes the RE industry. The Solar Boost 50 is one of those products, and RV Power products is in the process of obtaining a patent on their MPPT technology. The real world performance of the Solar Boost 50 is roughly equivalent to having two extra PV modules on our tracked array. Considering that the cost of the Solar Boost is less than the cost of a single module, this controller is not only energy effective, but also cost effective. If you are not using a Solar Boost 50 MPPT charge controller in your system, you're wasting some of your expensive, PV-produced power.

**Access**

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# Things That Work

*Tested by Home Power*

# Zephyr Industries' Power Vent

**Tested by Joe Schwartz**



Anyone who has worked around batteries knows the potential dangers of the technology. RE system installers grumble after a heavy morning of hoisting batteries full of lead and sulfuric acid. A few days later, just as the back's finally feeling up to snuff again, your new pair of work pants or yet another T-shirt begins to rot away. Another chunk of your shrinking wardrobe succumbs to sulfuric acid.


**Danger!**
Contact with battery acid should be taken very seriously, and minimized with gloves and eye protection. But the more serious danger posed by batteries is found in the hydrogen gas they produce while charging. Hydrogen is the lightest element in the universe, virtually impossible to contain, and to top it off, it has seriously explosive tendencies.

Hydrogen gas poses an explosive threat at concentrations as low as 4 percent. Some people have been unlucky enough—or careless enough—to witness the hazard of hydrogen gas firsthand. Stories circulate of sparks created while working on battery banks that ignited hydrogen gas and blew the sides right out of one or more batteries, disgorging acid everywhere.

**The Problem**
Sealed batteries minimize both electrolyte leaking and gassing while batteries are under charge. But these batteries are two to three times more expensive per watt-hour stored than flooded lead-acid cells. They also require more accurate control of battery voltage, since they will not tolerate high voltage levels. The majority of RE systems use flooded lead-acid cells, which are subject to gassing.

When using flooded cells, the best approach to keeping hydrogen gas at a safe level is to employ an active ventilation system. The Power Vent, manufactured by Zephyr Industries, uses a DC fan and standard 2 or 3 inch schedule 40 PVC pipe to draw hydrogen gas out of the battery box and route it outdoors. A typical Power Vent installation uses one of the auxiliary relays in the Trace SW series inverters, or a voltage controlled switch, to operate the fan automatically based on battery voltage. The Power Vent is a low-cost and effective means of ventilating your battery containment and reducing the occurrence of high concentrations of hydrogen gas.

**Keep the Cold Air Out!**
The Power Vent also provides a solution to a very basic problem with battery containments. For optimum performance, we want to keep lead-acid batteries as close to 78°F (25°C) as possible. So battery containments should be well insulated. But we run into a catch-22, because we also want to vent the battery box to the outside to reduce the concentration of hydrogen gas.

When we add a vent, we've put a big hole in our well-insulated battery box. Because of indoor and outdoor temperature differentials, cold air is often drawn through standard exhaust vents and right into the battery box. As cold air settles to the bottom of the box, it displaces the warmer indoor air and can actually create a backdraft that pushes hydrogen gas into the power room.

Zephyr Industries, out of Salida, Colorado, is a small company that specializes in RE system design and installation. They began manufacturing

the Power Vent in 1996 in response to customer concerns of cold air infiltration into their battery containments.

The Power Vent uses a simple, gravity-operated backdraft damper to minimize cold air flow into the battery containment. When the fan is running, the damper is pushed open and air transfer occurs. When the fan is not running, the damper returns to a closed position. For the backdraft damper to operate correctly, the Power Vent must be mounted vertically and right-side up as indicated on the unit's casing.

**The Power Vent**

Zephyr Industries Power Vent is available in 12, 24, and 48 VDC models. The casings for 12 and 24 VDC Power Vents are made from 3 by 2 inch PVC bell reducers, and accept 2 inch PVC for both intake and exhaust. Because the 48 VDC model moves a higher volume of air than the lower voltage units, its casing has a 3 inch output diameter.

The 12 and 24 VDC vents draw a maximum of 3 watts and move an air volume of 6 cubic feet per minute (cfm). The list price on the 12 and 24 VDC Power Vent is US$79. The 48 VDC model draws a maximum of 6 watts and moves an air volume of 8 cfm. The 48 VDC model has two, stacked 24 VDC fans wired in series, and retails at US$104. The Power Vent has a two year warranty.

The fans used in the Power Vent are brushless and do not create sparks that could ignite the hydrogen gas. The fans have a design life rating of 50,000 hours. Do the math—that works out to a life span of over seventeen years. This assumes that the fan operates for an average of eight hours a day, while the batteries are charging.

**Automatic Control of the Power Vent**

The Power Vent can be controlled by the auxiliary signal relays in the Trace SW-series inverters. And because of its very low power draw, it can actually be switched directly via the relay too. (Many loads that are controlled by these relays require a second, high-current auxiliary relay to handle the actual load current. The relay in the Trace simply handles the control signal current for the larger relay.) This relay setup enables the fan to be turned on or off automatically, based on battery voltage. When the batteries reach a voltage where gassing occurs, the fan is turned on.

If your RE system doesn't include a Trace SW series inverter, the Power Vent can still be easily automated using a voltage-controlled switch manufactured by Solar Converters Inc. This switch is rated for 30 amps at 12 to 60 VDC, and will control fan operation based on battery voltage. A 1 amp fuse should be installed in the positive leg of the fan wiring. This will protect the fan, the inverter's relay, and the wiring in the event of a short in the fan/relay circuit.

**Safety Is Worth It**

The use of a Power Vent and active ventilation of battery containments makes sense, plain and simple. When you consider the hardware cost of your RE system, a Zephyr Industries Power Vent amounts to an extremely small percentage of the total system cost. It's a small price to pay for the safety it provides.

**Access**

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"The man who on his trade relies
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Sir Thomas Lipton — 1870

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# Lead-Acid Battery Desulfator

Homebrew

Alastair Couper



It was twenty years ago that I left my on-grid home, and my job as an electronics engineer, to begin life on an alternative energy oriented organic farm. In the intervening years, I have installed, maintained, and experimented with numerous RE systems in my area. What I have come to understand from this experience is that off-grid life tends to become very much focused on the battery bank and its fate.

All power sources and loads breathe through this crucial pathway. Batteries are heavy, toxic, inefficient, and—to the amazement of many—electrically very fragile. Weak or failing batteries are a very likely cause of breakdown, especially in smaller solar-electric systems.

Most newcomers to renewable energy are quite familiar with using water tanks or gas tanks, and naturally use this familiarity in trying to understand their battery banks. Everyone knows that a bigger water tank is better than a small one. Unfortunately, batteries are not like tanks, and the result is trouble.

It is definitely not true that a big battery bank is necessarily better than a small one. An oversized battery bank can be almost impossible to charge properly. Without a minimum daily exercise regimen, it can become the equivalent of a couch potato. The main culprit is sulfation, which is a gradual crystallization of the battery's plate material, rendering it electrically inactive.

### Some Theory

Past issues of *Home Power* (see Access) have gone into the details of keeping lead-acid batteries healthy, so I will only touch on the main points here. The usual practice in maintaining a battery in good condition is to apply a periodic equalization charge over and above what would be a normal full charge. Unfortunately, this is an energy-wasting tactic. It ultimately results in clean battery plates, but at a steep price, especially if the energy must come from a generator.

I initially went to the Internet to find any available information on the problem of sulfation. The search engines turned up several commercial sites that give useful details on the fine points of battery charging and equalization. A second resource is the IBM patent server (www.patents.ibm.com). I found relevant patents there, using keywords like "desulfate" and "rejuvenate."

What this wealth of data shows is that there are numerous strategies for charging and electrically desulfating batteries. Most of them were designed or developed in the last twenty years or so. Considering that lead-acid batteries have been around for more than a century, this is a relatively new innovation. Virtually all of the devices and patents I found have in common the use of some form of pulsing charge current. This is in contrast to the constant or slowly varying currents generated by sources like solar-electric panels.

I distilled and simplified these various techniques, and came up with a basic circuit that will keep small to medium sized batteries in desulfated condition. It can even be used to bring old, sulfated units back into service. Use of the circuit has dramatically reduced the need for equalization charges in my own home system.

### Resonant Frequency

The technique used in this circuit relies on a little known aspect of lead-acid batteries. They possess what is called a "resonant frequency," at a surprisingly high frequency. The frequency is dependent on various physical details of the battery's construction, but it is on the order of 2 to 6 megahertz, which is in the low ranges of the shortwave radio bands.

**Figure 1: 12 Volt Battery Desulfator**

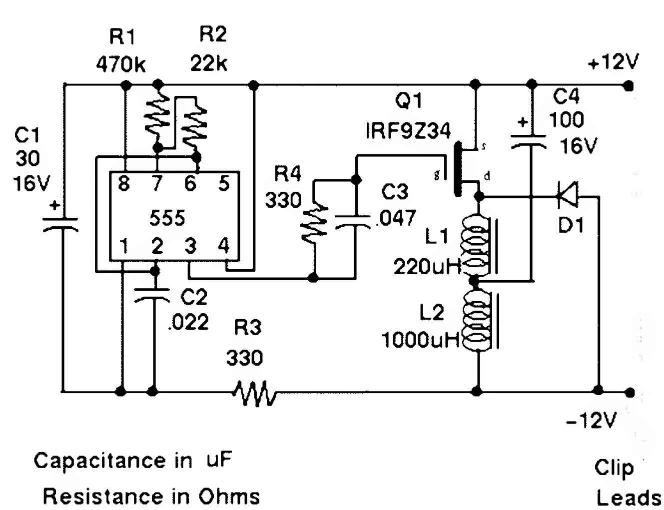
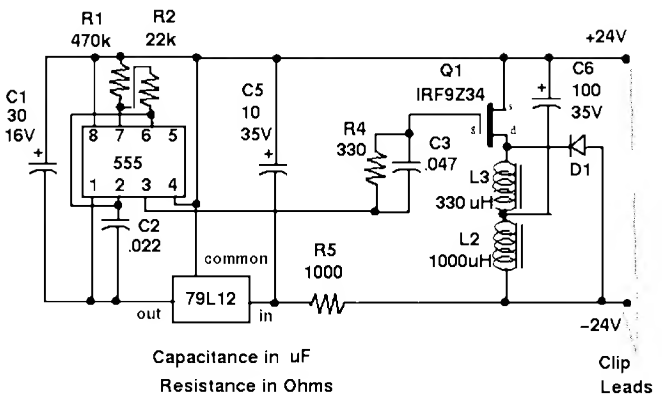


**Figure 2: 24 Volt Battery Desulfator**




This resonance is just like that of a stringed musical instrument, where a pluck of the string creates a vibration of a specific tone. In the case of the battery, sulfur ions dissolved in the electrolyte take the place of the string. A sufficiently energetic electrical "pluck," or pulse, will cause a similar vibration of these ions, back and forth throughout the electrolyte.

When this vibrational state is occurring, there are uncountable collisions between the ions in the electrolyte and the battery plates, as the back and forth vibration continues. It is this rhythmic beating of the plates which causes the breakup of the crystalline deposits, slowly but surely, for as long as the electrical pulsations are applied.

It is not unlike sandblasting a rough surface, but on a micro-physical level. This is an advantage of electrical methods over the use of chemicals like EDTA. Rather than dissolving the sulfate deposit and allowing it to settle on the bottom of each cell, as with EDTA, the pulse technique returns the sulfate back into solution again.

**Circuit Details**

The circuit is in essence a very widely used form of switching DC-to-DC convertor, which can take a DC voltage and step it up to a higher level. Figure 1 shows the version which is specifically for 12 volt systems. The basic pulse rate is set by the venerable 555 timer chip, U1, which switches the MOSFET Q1 at a 1 kHz rate.

When Q1 is in the non-conducting state, current is drawn from the battery through L2 so that capacitor C4 can be charged slowly. Then Q1 is turned on for a brief 50 microseconds, causing the charge stored in C4 to start flowing through L1.

When Q1 is turned off again, the stored inductive energy in L1 has to continue to flow somewhere, so it pulses back into the battery through diode D1. This current pulse can get as high as 6 amps. The use of an inductor to supply this pulse is what makes it possible to restore badly sulfated batteries with a high internal resistance. The peak voltage drop across the battery can initially be as high as 50 volts. With continued treatment, this peak voltage will decrease as the battery's internal resistance gradually declines.

Figure 2 shows the version for use in 24 volt systems. Its only additional feature is the use of a 79L12 voltage regulator (component U2, Digi-Key part number NJM79L12A-nd) to convert the 555's input voltage down to 12 volts. Also L3 (Digi-Key part number DN4518-nd) is increased in value over L1 in the 12 volt unit, to compensate for the higher terminal voltage.

**Lead-Acid Battery Desulfator Parts List**

| *Item* | *Component* | *Description* | *Cost (US$)* |
|---|---|---|---|
| Q1 | IRF9Z34 | P channel MOSFET | 1.82 |
| U1 | LM555CN | Timer IC | 0.42 |
| U2** | 79L12 | 12 V regulator | 0.36 |
| D1 | GI826CT | Fast recovery diode, >6 A, 100 V | 0.77 |
| C1 | 30 µF, 16 V | Electrolytic | 0.23 |
| C2 | 0.022 µF | Disk ceramic | 0.38 |
| C3 | 0.047 µF | Disk ceramic | 0.54 |
| C4* | 100 µF, 16 V | Electrolytic, low impedance type | 0.44 |
| C5** | 10 µF, 35 V | Electrolytic | 0.23 |
| C6** | 100 µF, 35 V | Electrolytic | 0.49 |
| R1 | 470 kΩ | 1/4 W | 0.15 |
| R2 | 22 kΩ | 1/4 W | 0.15 |
| R3* | 330 Ω | 1/4 W | 0.15 |
| R4 | 330 Ω | 1/4 W | 0.15 |
| R5** | 1 kΩ | 1/4 W | 0.15 |
| L1* | 220 µH (nominal) | Ferrite inductor, 6+ A peak | 2.08 |
| L2 | 1000 µH | Ferrite choke, 100 mA | 3.12 |
| L3** | 330 µH | Ferrite inductor, 6+ A peak | 2.08 |
| | Case | Aluminum project box | 5.44 |
| | Clip leads | Alligator type, insulated (RS) | 1.00 |
| | Board material | 0.1" spaced copper pads | 3.00 |
| | | *Total for 12 V Unit* | $19.84 |
| | | *Total for 24 V Unit* | $20.48 |

* For 12 V unit only.
** For 24 V unit only.

If an oscilloscope is available, it is easy to observe the ringing wave form across the battery terminals. It is likely that more than one frequency will be apparent, due to all the wiring and other details of the setup. It should be possible to see a small spark jump from the leads of the pulse generator as it is connected, a result of the high peak voltage available (keep this in mind if your batteries are not well ventilated). Depending on the case, and the type of inductors used for L1 and L2, a faint audio tone can also be heard when the circuit is operating. Digi-Key part number DN4516-nd will work for L1, and DN7437-nd will work for L2.

There is no reverse polarity protection in this circuit, so make sure that the leads are clearly marked. A mistake will result in damaged components. Also, it is not a good idea to expose the 12 volt circuit to more than 16 volts at the terminals.

See the parts table for a detailed component list. But don't get too attached to using exactly these components, or to buying new stuff. The homebrew ethic is based on an ability to make do, come up with alternatives, and recycle. My first trial units had quite a bit that was clipped out of old junk circuit boards.

**Usage**

It should be emphasized that pulsing energy to and from the battery happens at less than 100 percent efficiency. This circuit draws about 40 mA from the battery while in operation (less than 1 amp-hour per day), so some additional charging source is needed. For reconditioning a sulfated battery, I simply clip the circuit across the battery terminals in parallel with a 30 watt solar panel.

In my initial testing, it took a month to partially reclaim a pair of golf cart batteries that had been allowed to sit, discharged, for almost a year. They had such a high internal resistance that a very small current would take the terminal voltage over 16 volts.

For use in a functioning power system, you can clip the circuit across the main battery terminals, using as short a lead length as possible. When external equipment, such as an inverter, is connected across a battery bank, then additional low impedance paths are formed. The desulfator's current pulses will happily flow down these paths as well, and it serves no purpose for the pulses to flow into the inverter.

I had initially thought that this shunting, or dilution, of the current pulses away from the battery would be a problem. This has not proven to be the case, however, because the impedance of typical inverters at frequencies above 1 megahertz is not very low. (Note: impedance is just a fancy word for resistance, taking into account the circuit's behavior at different frequencies.)

One way to keep the external equipment from shunting away the current pulse would be to take some ferrite toroid cores and slip them over the battery leads as they leave the bank. This will increase the high frequency impedance without affecting the DC performance of the circuitry.

The circuit as shown, with its approximately 6 amp peak capacity, is probably strong enough to maintain a bank of several hundred amp-hours. If you want to use the circuit with larger banks, it will be necessary to select D1, L1, and L2 for higher current capacity. You will also need to vary the pulse width from the 555 accordingly, so that Q1 is allowed to stay on for a longer period of each cycle. If you want to power the circuit from an auxiliary voltage source, so that the battery being treated remains trickle charged, simply remove R3 and place 12 volts across C1.

It's best to construct the unit in a shielded case. Otherwise it is likely to generate a fair bit of radio interference. The use of the shortest possible lead length is also a good idea. All the components are available from any general electronics distributor. Radio Shack is as good a place as any for getting the case, clip leads, circuit board, and other components.

**Does It Work?**

If badly sulfated batteries are treated, it is convenient to use a trickle charger of one or two amps. In this case, the simplest way to see that the circuit is having an effect is to note that the terminal voltage actually *drops* each day as the batteries slowly charge. This is a result of the internal resistance of the cells decreasing as the plates become slowly cleared of the sulfate, and more useful plate area comes in contact with the electrolyte. Also, the specific gravity of the cells begins to rise slowly, evidence that the sulfate is going back into solution.

To further check the progress, you could do a discharge test, using a known load, to determine the useful capacity. This would involve measuring the length of time taken by the load to drop the battery voltage from a high level to a low level. If you repeat this test, a gradual lengthening of this interval should be noted.

In one system I worked with, at first the batteries would not power even a small load. After treatment, they were able to run loads in the neighborhood of 5–10 amps for a few hours. This is far from "like new" condition, but it was sufficient for them to be returned to use in the small PV system they were taken from. I expect that further treatment would have helped. It seems that the process

is inherently slow. Lead sulfate is just not very willing to return into solution.

**Healthy Batteries**

I have used this circuit in my main system for over a year, and have not seen the need to equalize in that time (I do not own a generator). All of the cells' electrolyte levels remain in step with each other, and there has been no problem with starting big loads—a sure sign of battery health. Patience is required in reclaiming weak and tired batteries, and no amount of desulfating will help a battery with a shorted cell, or one that has lost plate material through excessive use.

The device is especially useful for automotive batteries that sit for long periods. If you use a generator for equalization, this technique is a must. When you live off-grid, silence is golden.

**Access**

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Web sites of interest:
www.batterybes.com • www.innovativeenergy.com

*Home Power* articles:
*Batteries: How to Keep Them Alive for Years and Years…,* by Windy Dankoff, *HP69,* page 46.

*Batteries: What We Know About Them; How to Use Them,* by John Wiles, *HP58,* page 66.

*Preliminary Notes from the EDTA Trenches,* by Stan Krute, *HP 21,* page 36.

*New Life for Sulphated Lead-Acid Cells,* by Richard Perez, *HP20,* page 23.

# TOP SECRET

## GUERRILLA SOLAR: the unauthorized placement of renewable energy on a utility grid.

## PROFILE: 0010

**DATE:** May, 2000

**LOCATION:** Northern Hemisphere

**INSTALLER NAME:** Classified

**OWNER NAME:** Classified

**INTERTIED UTILITY:** Classified

**SYSTEM SIZE:** 800 watts of PV

**INTERFACE DEVICE:** Trace SW4024

**PERCENT OF ANNUAL LOAD:** 3%

**TIME IN SERVICE:** 15 months

This system consists of approximately 800 peak watts of PV on a fixed pole mount. Eight Trojan L-16 batteries connected in series/parallel yield a storage capacity of 700 AH at 24 VDC. Battery charge is regulated by a Heliotrope CC-120 charge controller in the event of utility failure. A Trace SW4024 inverter is used to supply dedicated circuits in both the house and garage. AC inputs to the SW4024 consist of both a 30 amp utility source and a small 3 KW diesel generator.

Our location and weather patterns are far from ideal for solar insolation in the winter. During the summer months, we would normally run our dedicated circuits directly from the PV system with the utility serving as backup. This usually worked OK, but did require periodic recharge from the utility. As our children grew older, their power thirst increased substantially. This caused more frequent need for utility intervention.

The decision to intertie made total sense in our case. We had spoken with our local utility several years ago about interconnecting, and got the usual packet of legal documents, disconnect requirements, and red tape. After carefully examining the safety features of the Trace inverter, I was confident of its ability to safely intertie with the utility. After all, the only difference between intertie or not is the simple push of a button. If the inverter could not accomplish this safely, it would not have received its listing from the testing laboratory. So push the SELL button we did!

When in the sell mode, the inverter maintains the battery setpoint voltage by dumping excess power to the utility. The Heliotrope CC-120 voltage setpoint is set slightly higher than the sell value in the inverter. This allows the CC-120 to regulate battery voltage in the event of utility failure or when operating in the stand-alone mode.

We now have the best of both worlds. Our ten year old battery bank is now always full, ready to supply our needs during a utility outage. No longer cycling the batteries will add several years to their remaining life span. With our configuration, all available PV power is first used to supply our loads. Any remaining energy is fed to the utility. No more wasted KWHs during those rare sunny winter days!

# Electric Vehicle Cost Comparison—Does an EV Make $ense For You?

David Brandt



I'm a mechanical engineer living in Claremore, Oklahoma. I've been interested in renewable energy and electric vehicles for some time now. I've not yet taken the plunge, but when the price of gas recently started rising, I decided to see if an electric vehicle (EV) would make good sense for me.

My 1986 Chrysler LeBaron coupe got about 30 mpg when I bought it, but over the years, normal wear has taken its toll. It now gets between 21 and 25 mpg, averaging about 22.5. This is still pretty good (especially compared to most newer cars), but for a daily commute of 32 miles (51 km) each way, the gas bills really start to add up.

A new or do-it-yourself (DIY) conversion EV was attractive to me for the commute, because of the low operating cost. Of course, I also had the option of keeping the LeBaron or getting a new car that got better gas mileage. I used a spreadsheet to analyze the finances for each option. The spreadsheet is not intended to account for every possible contingency—it's just for ballpark comparisons of different options. This article describes the spreadsheet, and what went into making it. The spreadsheet is available for download at the *Home Power* Web site. Once you download it, you can plug in your own numbers and see the results.

### Subjective Considerations

There is a lot to consider when making this kind of decision, and not everything can be turned into a number to put into a spreadsheet. The importance of each detail depends on the individual and his or her situation.

It gets *really* hot in Oklahoma in the summer. 110°F (43°C) was the high last year, with many weeks consistently above 100°F (38°C). You can imagine what cars feel like after sitting in the sun all day, even with the windows down (I'm so grateful I have cloth seats…). For me, this means air conditioning would be highly desirable. It might not be so desirable if you lived in, say, Minnesota or Michigan.

Most new gas-powered cars with acceptable mileage will be along the lines of a Ford Aspire or a Geo Metro. I just don't feel too safe in those tiny boxes, especially with all the behemoth trucks and SUVs on the road around here nowadays. I would rather keep my existing mileage and have a little protection than get 30 mpg and be a bump in the road to some careless Ford Excursion driver.

As you probably know, EVs do not directly produce emissions (one of the main arguments for their use). The indirect emissions produced by the power plant that makes the electricity to charge your EV are generally cleaner, and are produced in less volume than what a standard car would generate.

But I needed to answer some questions before switching to an EV. Would an EV go 32 miles (51 km) at highway speeds and still have the range to make it back at the end of the day? If not, would I be able to plug it in at work to recharge before going home?

All of these factors (and many others) have different weights for different people, and can be considered after calculating the dollar amounts. In other words, If you know that an EV will cost US$1,000 more (or less) over a ten year life, then you are in a better position to make your decision.

### Spreadsheet Layout

I set up an Excel spreadsheet to analyze four options.

- Buy a new electric car
- Perform a DIY conversion to make an electric car
- Buy a new standard car
- Keep my existing standard car

I wrote my spreadsheet in Microsoft Excel because it's what I am most familiar with. Excel is an application that makes repetitive calculations, graphing, and analysis of any kind of numbers really easy. "What-if" studies can be performed just by changing one number to see how it affects the others. If the results are not what you need, it only takes a couple of seconds to change the number back.

Excel is available for both IBM and Mac, and typically costs about US$200 by itself. This varies widely, as it can be purchased in several versions, and packaged with several other groups of programs, most notably

Microsoft's "Office" package. Older versions may cost less. Personally, the best spreadsheet deal I have found is Microsoft's "Worksuite" package for US$99. It includes full versions of Word, Money, several other programs, and Works. Works includes a spreadsheet that is just as capable as Excel, although it does not have all the features.

Items in blue text on the spreadsheet must be entered by the user. The computer calculates the other numbers. The annual operating costs for each vehicle option, assuming all of them are used in the same manner, are calculated.

In my case, my usage is 32 miles (51 km), twice a day, each weekday, for a total of 320 miles (515 km) per week. The operating costs include insurance, fuel (or electricity), and miscellaneous maintenance. Registration, inspection, etc. may be included by adding them to the maintenance or insurance costs, but since they will be pretty much the same for all the options, I didn't put them in explicitly. The initial costs, salvage value, and any intermittent costs, such as replacing a battery pack every few years, are taken into account in the spreadsheet.

Standard engineering economics factors are used to calculate the equivalent cost for each option, as if you were to spend all of it today (the "present worth," or in our case, the "present cost"). These factors correct for inflation.

Please note that I did *not* consider getting a loan in any of these options. To account for a loan, you could put the down payment under "initial cost," and include your payments (already corrected for loan interest) under either the insurance or maintenance categories. You would then have to make sure the life you use for comparison purposes is as long as the loan. You would also have to assume the same loan terms for each option that you want to consider a loan for.

**Inputs**

For the EVs, user input includes recurring maintenance costs, insurance, and battery pack size (to calculate recharge cost). Recharge costs are calculated assuming a 90 percent conversion efficiency, and that 80 percent of the battery pack capacity needs to be replenished.

For the standard cars, user input includes mileage, insurance, and recurring maintenance costs. In addition, my car burns some oil, so in the "Keep Existing Standard Auto" category, I added the cost of oil and oil consumption per week as inputs. Just out of curiosity, I increased oil consumption to a significant amount to see what would happen. Interestingly, it barely made a difference in the annual operating cost.

Theoretically, it costs more per year to maintain a car for every year you keep it. This being the case, I added a "maintenance gradient" factor to the "Keep Existing Standard Auto" category as an input. The gradient factor is the estimated amount the maintenance cost will increase each year. For example, if my regular recurring maintenance cost is $100, and the gradient is $100 per year, then what I am saying is that my maintenance costs for the first year will be $100, for the second year they will be $200, for the third year they will be $300, and so on.

Other user inputs are the life span for comparison purposes, estimated annual inflation rate, the cost to replace a battery pack, and the number of years between battery pack replacements. Incidentally, the spreadsheet assumes that replacing a battery pack will cost the same for either a purchased or DIY conversion EV. It also assumes that the battery life will be the same for either. The comparison life is the amount of time you expect to keep using the vehicle. For an apples-to-apples comparison, all of the four options are assumed to last this long.

Integrating the battery pack replacement costs is tricky. I first calculate the number of times they will have to be replaced over the comparison life of the vehicle. Now, here's how the human brain differs from Excel: if I have a four year battery pack life, and am comparing costs over ten years, I intuitively know that I will have to include the replacement costs at four years and eight years.

Excel, on the other hand, has no way to put this calculation into a formula (none that I know of, anyway). I "hard-wired" the calculations into the cost formulas using a string of nested *if-then-else* statements. The only real disadvantage to this method is that it requires typing a very long formula into each cell. To keep the formulas short, and limit the comparison to a realistic time frame, I only allowed for a maximum of four battery pack replacements over the comparison life. I have read estimates of battery pack life that range between three and ten years, so this should be adequate.

The only limitation, besides the number of battery pack replacements mentioned above, is that the time intervals must be entered in whole numbers of years. For example, you cannot compare over a life of 5.67 years, or replace batteries every 4.33 years. You would get a number, but it would be meaningless.

**Outputs**

After entering all the values in blue, look at the "Calculated Comparison of Present Cost" row to see how you will fare financially with each option. It is a snap to run what-if studies by varying prices, interest

## Spreadsheet Fields Explained

**User Inputs**

- Initial cost: What you initially pay for the vehicle. For the DIY conversion, this cost is for all the pieces. No labor is included in my example, but if you know how much it is, you can add it to the initial cost.
- Salvage value: The amount you think you can sell the vehicle for at the end of the time period you are comparing.
- Insurance for six months: Cost of six months of car insurance for the vehicle.
- Battery pack voltage: Traction battery pack voltage. This is used to calculate the cost to recharge the EV. Keep in mind that different voltages give different range and speed characteristics, too.
- Battery pack amp-hours: Amp-hour capacity of the battery pack. Again, this is used in calculating the cost to recharge the EV.
- Miscellaneous maintenance per year: Miscellaneous maintenance costs for one year (shocks, belts, etc.). This tends to be higher with older vehicles.
- Mileage: The gas mileage you are getting or expect to get.
- Oil price per quart: The price of oil per quart.
- Oil consumption: Quarts of oil consumed per week.
- Maintenance gradient per year: The amount you expect maintenance costs to increase each year.
- Annual rate of inflation, $i$: The estimated annual rate of inflation in percent.
- Comparison life, $n$: The number of years that all the cars in the comparison are assumed to last.
- Battery replacement interval, $n_2$: The number of years between battery pack replacements.
- Usage: The number of miles you expect to use the vehicle per week.
- Gas cost per gallon: Cost for a gallon of gas.
- Electricity cost per KWH: Cost per kilowatt-hour for electricity.
- Cost to replace battery pack: Replacement cost for the EV battery pack.

**Calculated Values**

- Recharge KWH (90% efficiency, 80% DOD): The number of kilowatt-hours to recharge the EV, assuming that there is a 90 percent transfer efficiency between the meter and the EV, and that the batteries are 80 percent drained (depth of discharge) when they are recharged.
- Cost per full recharge: The cost to recharge the EV, given the cost per kilowatt-hour entered by the user, and the number of kilowatt-hours calculated by the spreadsheet.
- Operating cost per week: This adds up gas (or electricity) costs, miscellaneous maintenance, insurance, etc. This is how much it costs to operate the vehicle every week.
- Operating cost per year: Operating cost per week, multiplied by 52.
- Gallons per week: How many gallons of gas the car uses each week based on the mileage input by the user.
- Gas cost per week: How much you will spend on gas each week.
- $p/a$ factor (at $i$ and $n$): What payment today is the same as an annual payment over $n$ years at $i$ percent interest (or inflation) rate?
- $p/f$ factor (at $i$ and $n$): What payment today is the same as a payment $n$ years in the future at $i$ percent interest (or inflation) rate?
- $p/g$ factor (at $i$ and $n$): What payment today is the same as an annual payment that increases by $g$ dollars every year, at $i$ percent interest (or inflation) rate? The $p/g$ factor is used with the $p/a$ factor. $p/g$ only considers the increasing amount. The initial annual amount is considered by the $p/a$ factor.
- End-of-year convention: Assumes all payments take place at the end of the year in which they occur. This convention is commonly used for economic analyses, and is necessary to use the factors described.

rates, life spans, etc. You can also input zero costs for items. For example, if you have an RE system that will provide power for your nightly recharges, you could set the electricity cost to zero. If your car doesn't burn oil, set the oil consumption rate to zero. If you don't have insurance, well, we won't go there….

You are probably wondering how I fared. After entering approximate values for items in my area, the results were as follows.

| | |
|---|---|
| New Electric | US$20,702.14 |
| DIY Electric Conversion | US$16,902.17 |
| New Standard | US$28,156.87 |
| Keep Existing Standard | US$18,522.92 |

As you can see, a DIY EV conversion has a cost advantage of about US$1,500. This comparison was made assuming an inflation (interest) rate of 3.5 percent, a comparison life of ten years, and a gas cost of US$1.50 per gallon. The difference drops rapidly when you lower the price of gas. When I lowered the

## Standard vs. Electric Car Comparison

| *User Input* | *Buy New Electric Auto* | *DIY Electric Conversion* | *Buy New Standard Auto* | *Keep Existing Standard Auto* |
|---|---|---|---|---|
| Initial cost | $11,000.00 | $7,500.00 | $15,000.00 | - |
| Salvage value | $3,000.00 | $2,250.00 | $0.00 | $0.00 |
| Insurance for six months | $275.00 | $200.00 | $275.00 | $200.00 |
| Battery pack voltage | 144 | 144 | - | - |
| Battery pack amp-hours | 120 | 120 | - | - |
| Miscellaneous maintenance per year | $100.00 | $150.00 | $200.00 | $225.00 |
| Mileage | - | - | 30 | 23.5 |
| Oil price per quart | - | - | - | $1.00 |
| Oil consumption (quarts per week) | - | - | - | 0.25 |
| Maintenance gradient per year | - | - | - | $125.00 |
| *Calculated Based On User Input* | | | | |
| Recharge KWH (90% efficiency, 80% DOD) | 15.36 | 15.36 | - | - |
| Cost per full recharge | $1.54 | $1.54 | - | - |
| Operating cost per week | $20.18 | $18.26 | $30.42 | $32.69 |
| Operating cost per year | $1,049.36 | $949.36 | $1,582.00 | $1,700.13 |
| Gallons per week | - | - | 10.67 | 13.62 |
| Gas cost per week | - | - | $16.00 | $20.43 |
| *Calculated Comparison of Present Cost* [1] | -$20,702.14 | -$16,902.17 | -$28,156.87 | -$18,522.92 |

| *User Input Constants* | *Amount* |
|---|---|
| Annual rate of inflation (*i* %) | 3.5 |
| Comparison life (*n* years) [2] | 10 |
| Battery replacement interval ($n_2$ years) [2] | 5 |
| Usage (miles per week) | 320 |
| Gas cost per gallon | $1.50 |
| Electricity cost per KWH | $0.10 |
| Cost to replace battery pack | $2,000.00 |
| # of battery replacements over comparison life | 2 |

| *Factors* | *Present Worth* |
|---|---|
| *p*/*a* at *i* and *n* [3] | 8.316605323 |
| *p*/*f* at *i* and *n* [4] | 0.708918814 |
| *p*/*g* at *i* and *n* [5] | 35.06906244 |
| *p*/*f* at *i* and $n_2$ [3] | 0.841973167 |

*Assumptions:*
The end-of-year convention is adhered to.
Salvage values are actual values received at sale.
Batteries are drained 80% of capacity each usage.

[1] Each option is reduced to a present cost; the least is the best. Some items cannot be included due to their subjective nature, such as the need for extra range, extra speed, air conditioning, etc.

[2] Warning: time periods *n* and $n_2$ must be in whole numbers.

[3] Present worth of annual payment *a* paid every year over *n* or $n_2$ years at *i* interest rate.

[4] Present worth of *f* paid *n* years in the future at *i* interest rate. Future worth *f*, or the value at some future time, corrected for interest or inflation over a time period.

[5] Present worth of a payment that increases at a given rate over *n* years at *i* interest rate. All amounts in US$.

gas price to the current price in my area of US$1.40 per gallon, the difference dropped to US$1,000.

This is where the subjective points come in. A cost advantage of US$1,500 over a ten-year life span for me does not outweigh the advantages of my present car. These include having air conditioning (which has already been converted to non-ozone-depleting refrigerant, by the way), and having the increased range and speed of the standard auto. At least for now, I will keep the LeBaron. If I had less driving to do, and didn't need air conditioning, I would probably opt to do the conversion. Besides, it sounds like fun.

**Drive Conservatively**

Incidentally, I have managed to increase the mileage of the LeBaron to over 25 mpg through simple conservation measures. First of all, regular, careful maintenance keeps emissions down and mileage up. Next, I keep the tires inflated towards the high end of their recommended range (it is stamped on the tire). I discovered that one tire had a very slow leak that lost about 5 psi per month. Little things like that rob mileage, and change handling characteristics.

Most highway speed limits around here are 65 or 70 mph (105 or 113 kph). I drive 55 to 60 (89–97 kph), and avoid jackrabbit starts. Cars use more gas for less motion when you accelerate hard. The last measure may sound weird—and to be honest I have no idea why it works—but I fill up when the tank is about half full. I had always heard that cars got better mileage while the

tank was closer to full, and I decided to try it out. It seems to be true.

**Old Car vs. New Car**

Interestingly, although car salesmen would lead you to believe otherwise, a new standard auto is by far the most expensive option. I assumed a zero maintenance gradient, 30 mpg, and an initial cost of only US$15,000. Actually, given today's car market, even a good car one or two years old would cost in excess of US$20,000. And 30 mpg is a high mark for newer cars, because of the demand for larger, more powerful engines.

And remember, this spreadsheet does not consider loan interest! Pull up a loan calculator on the internet (try the one at www.excite.com/autos by clicking on "calculate a car loan"), and you can see just how much interest you wind up paying. In addition, insurance rates are considerably higher for newer cars around here. All these costs really add up. I conclude that there is no mechanical or financial reason to replace a car unless it would cost more to repair than to replace.

**Use the Tools**

It's easy to see that there are a lot of things to be considered when comparing vehicles, electric or otherwise. Other factors include individual situation, location, and driving habits, in addition to these financial considerations. I hope that this spreadsheet and the various experiences discussed in this article will provide you with some tools to help you make a more informed decision.

**Access**

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The *Home Power* Web site (www.homepower.com) has links to some great Web sites about EVs, such as Electro Automotive, the Electric Auto Association, and Jerry Halstead's Web chronicle of an EV conversion.

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# Putting the Fuel into Fuel Cells

Shari Prange



Suddenly, fuel cell cars are replacing electric cars in the public mind as the "cars of the future." Of course, in reality, fuel cell cars *are* electric cars. They use the same type of electric motor to drive the wheels. The only difference is the source of the electricity. Instead of batteries, they use fuel cells.

Both batteries and fuel cells are boxes in which a chemical reaction creates electricity. Batteries are energy *storage* devices, and are recharged by plugging them into a source of electricity, through a charger. By contrast, fuel cells are energy *conversion* devices. They are not "recharged." Instead, they must have a fuel tank to supply them with fuel. This fuel is then converted to electricity. Let's look at the pros and cons of fuel cell systems.

**Shades of Gray**

First, we need to recognize that the fuel cell itself is only part of the fuel cell system. Even though all fuel cells use hydrogen, there are many ways of producing the hydrogen and getting it to the fuel cell. Usually this involves processing some type of fuel through a "reformer" to extract hydrogen from it.

Each method has advantages and disadvantages, depending on which factors you examine. To determine the true value, you have to look at the complete fuel picture, "from well to wheel." While the fuel cells themselves are "zero emission" devices, the processes that deliver the fuel to the fuel cell usually are not.

Dr. Sitaram Ramaswamy is associate director of the Fuel Cell Vehicle Modeling Program at the Institute of Transportation Studies, University of California, Davis. According to Dr. Ramaswamy, it is nearly impossible to get clear numerical comparisons between the different systems, because the results depend strongly on assumptions and projections. There is very little hard data about how these systems will actually perform in ordinary mass-market cars.

We can't possibly cover all of the issues in this article. But we can look at some general characteristics of each hydrogen source. Some systems might be practical for industrial or fleet vehicles, but not for private cars. We'll focus primarily on issues as they might apply to ordinary people in daily driving.

**Water**

In many ways, water is the ideal source for hydrogen. It's clean, safe, and abundant. The problem is extracting the hydrogen from it. This is done through electrolysis, which is essentially the opposite of the process inside the fuel cell. In electrolysis, energy is applied to water to separate the hydrogen and oxygen. In a fuel cell, hydrogen is combined with oxygen, producing energy and water.

The cycle is not self-perpetuating, however, since there are losses in both processes. At present, electrolysis is too costly in terms of energy and money for this to be a practical source of hydrogen.

This leads to another issue. In order to evaluate the full environmental effect of electrolysis, you need to look at the source of the energy for the process. For it to be a truly clean process, it must be powered by clean energy, such as solar, hydro, or wind power.

A recent development may offer another way to extract hydrogen. Experiments have been done using algae to separate hydrogen from water. This is accomplished through alternately feeding the algae heavily, and then starving it. Right now the process is nothing more than an interesting laboratory experiment, but it might prove to be a viable technology (or, more accurately, biotechnology) at some point in the future.

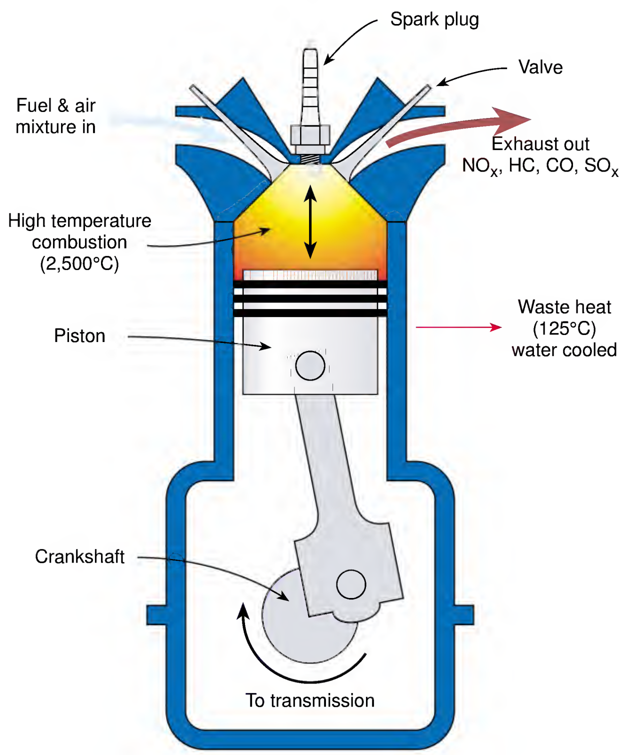
In any case, the process of extracting hydrogen from water is not something that can be done onboard the vehicle. You won't be filling your car's tank with water. Instead, it will be done at a stationary facility. The car will then carry hydrogen in tanks to feed the fuel cells. The necessary oxygen may be extracted from the air, or stored in onboard tanks.

**Onboard Hydrogen**

Hydrogen is normally a gas, which can be stored in a pressurized tank. But this is not a convenient way to carry it on a vehicle. There is too little fuel density in a gaseous fuel to provide any reasonable amount of range before the vehicle needs to be refueled.

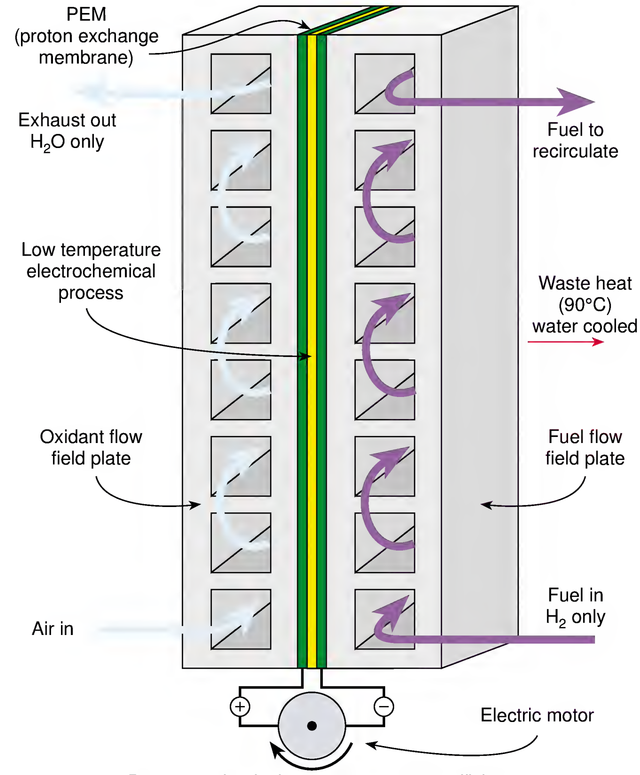
Liquid hydrogen can squeeze almost a thousand times the density into the same volume as gaseous hydrogen. However, it needs to be kept at -418°F (-250°C) to keep

**Single-Cylinder Internal Combustion Engine**




Rotary mechanical output: 20% power efficiency

**Single-Cell Hydrogen Fuel Cell Engine**




Rotary mechanical output: 45% power efficiency

it in liquid form. This requires a cooling apparatus and an insulated tank. These things add bulk, weight, and energy demands to the vehicle.

Hydrogen fuel also requires an entirely different fueling station infrastructure than the existing gas station network. According to the March, 2000 issue of *Automotive Industries,* "Experts estimate that it will take thirty to fifty years to build the necessary infrastructure to support hydrogen stations." While this sounds like an extreme position, it is true that establishing corner hydrogen filling stations would be a massive undertaking.

**Compressed Natural Gas**

Compressed natural gas (CNG) is a possible fuel source for fuel cells, but probably in an indirect fashion. It is not favored as an onboard fuel, because the overall vehicle efficiency is too low. Short range has also been a drawback for combustion-engine vehicles using CNG. That's why these vehicles are usually in fleets, "tethered" to their home base for refueling. If you're going to carry a gaseous fuel onboard, it would make more sense to carry hydrogen gas.

CNG is likely to be used in stationary reforming facilities. In fact, steam reformation of CNG is the cheapest way to produce hydrogen. The advantages of this process are that it can be done at the relatively low temperature of 482°F (250°C) and it produces a fairly hydrogen-rich (70% concentration) output.

The fuel processor, however, requires energy to maintain its operating temperature. It also requires a carbon monoxide (CO) clean-up section. The overall well-to-wheel efficiency and environmental impact of the process must take into account energy used or emissions produced "upstream" of the reformer to provide the CNG.

**Gasoline**

Most of the current development in the area of hydrogen fuel for fuel cell vehicles is focused on fuel processors using either methanol or gasoline as source fuels. The main advantage to gasoline is that we are already familiar with it, and have a vast infrastructure set up to handle it. Using it to power a fuel cell will yield about twice the miles per gallon of simply burning it in an internal combustion engine. Emissions are greatly reduced, though not eliminated.

Obvious disadvantages are that it is non-renewable, and can be used as a political weapon by countries supplying it, so it doesn't address the issue of energy security. And, of course, gasoline still entails all of the "upstream" pollution caused by the extraction and refining of petroleum. But there are other disadvantages that are specific to its use in fuel cells.

"Low" temperature reforming of gasoline is not possible at this time. Instead, it is reformed through a process called partial oxidation (POX), which typically occurs at temperatures around 1,500 to 1,800°F (815–982°C). Unlike CNG steam reformation, POX supplies its own heat, but the CO cleanup is an even bigger problem than it is with CNG. The concentration of hydrogen in the output is also lower, around 50 percent.

The fuel cell needs very pure hydrogen to work properly. Some contaminants merely lower the fuel cell's efficiency. Others actively poison the fuel cell. The gasoline we are all accustomed to using has many additives and impurities in it. Some are there to meet octane requirements, and some are there, ironically, to make it burn cleaner. There is also organic sulfur contamination. All of these are undesirable for a fuel cell.

Producing cleaner gasoline at the refinery involves costly changes in equipment. On the other hand, cleaning up the gasoline onboard the vehicle adds the cost, weight, and volume of the cleanup equipment. There are also questions about the long-term reliability of this arrangement.

**Methanol**

The other current favorite hydrogen source is methanol. Since it is a liquid at normal temperatures, the existing gasoline infrastructure could be easily modified to handle methanol. Methanol is a good candidate for onboard reforming. It is a "low" temperature process (540°F; 282°C), and is more efficient than gasoline reforming. Methanol fuel cell vehicles are virtually emission-free. While they do produce $CO_2$, it is much less than is produced by today's conventional vehicles.

There are some potential safety issues with methanol. It is toxic, odorless, colorless, tasteless, and burns with a low-visibility flame. The difficulty of detecting it would require special care in handling. And again, carrying the reformer onboard the vehicle adds cost, weight, and volume.

Vehicle fuel systems would also need to be redesigned, since methanol will corrode the types of fuel lines and seals normally used for gasoline. This is one of many reasons that converting an existing car to run on fuel cells would be more complicated than making a battery-type electric conversion out of the vehicle. It's not as easy as dropping some fuel cells into the trunk, and filling the fuel tank with methanol instead of gasoline.

Methanol can be produced renewably, from organic waste or timber residues. However, in the near term, the reality is that it is likely to be derived from natural gas, primarily for economic reasons. There is already a partial infrastructure in place for this process. Converting our energy industry to clean and renewable sources is, unfortunately, a long slow process.

**Diesel and Ethanol**

These are two fuels that are not considered viable for fuel cells. Diesel fuel is heavy, and reforming it is costly, due to the necessary clean-up of sulfur and aromatics. It is easier and cheaper to reform gasoline.

Likewise, ethanol is more difficult and costly to reform than methanol. Also, the overall energy efficiencies of raising the crops and producing ethanol from them are not good.

**Longevity**

Maintenance and longevity are also important issues. The Department of Energy goal for fuel reformers is a 50,000 mile (80,000 km) life span. No one is certain that that goal can be met.

This also depends on the type and quality of fuel that is being used. The more impurities there are in the fuel, the more stress on the reformers and fuel cells. Contamination will reduce the effectiveness of the system, and, as it accumulates over time, will eventually cause it to fail.

In large, stationary reformers, extra capacity can be built in to compensate for losses of function due to contamination, or "poisoning." However, in an onboard vehicle system, weight, volume, and cost are critical. It may not be practical or cost-effective to build this kind of extra capacity into a vehicle.

**Not Quite Ready**

The fuel cell vehicle still needs several years of development before it's ready to park in your garage. Neil Ressler, technology chief at Ford Motor Company, said, "Effective reformers exist only in the laboratory. Also, current fuel-cell designs do not work well in sub-freezing temperatures."

General estimates are that some fuel cell vehicles will begin to appear on the market in limited numbers by about 2004. The first ones will probably be methanol reformer vehicles, or onboard hydrogen vehicles, with gasoline reformers following a few years later as more complex technological problems are solved. As with the first battery-powered cars, these may be targeted for fleets, with vehicles for the general public lagging several years behind them.

Ballard Power Systems, Inc., of Canada, is one of the leaders in developing fuel cells for the automotive industry. They are working with both Ford and DaimlerChrysler. Paul Lancaster of Ballard believes that fuel cell systems will be cost competitive with conventional internal combustion systems when vehicle volume reaches 250,000 to 300,000 per year.

**A Pregnant Pause**

The automotive fuel cell, like most promising new technologies, captures the imagination at the moment of conception. Many technologies, however, don't survive. The ones that do must still go through a gestation period that may take several years. Even after they have left the womb of the laboratory and entered the marketplace, there will be years of growing pains before the technology is "mature."

Right now, the fuel cell car is starting to kick. We will simply have to be patient and wait for delivery.

**Access**

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# EV Tech Talk

**Mike Brown** ©2000 Mike Brown

**"I would like to convert my gas car to electric, but I don't know if I can do the job. What resources do I need?"**

This is one of the questions that comes up often in conversations at shows, over the phone, or by email. In answering this question, I am not going to get into what kind of car to convert, what parts are needed, or what batteries to use. All of these topics have been covered in earlier issues of *Home Power.* Instead, I am going to discuss the work space required, the tools necessary to do the work, and the knowledge and experience needed.

### Work Space

The work space issue is more complicated than you might think. While giving a class on conversions, I once said that to do a conversion you need at least a two-car garage that you can tie up for the duration of the conversion process. A hand went up in the back of the room, and a student asked, "What's a two-car garage?" I had forgotten that I was in an area where most people live in apartments or condos.

The minimum amount of space needed is enough room to house the car being converted with all its doors wide open. To that, add enough room for a six foot (1.8 m) long workbench. This amount of space will give you access to all parts of the car, and a flat area other than the floor to work on.

You should also have enough room to store the parts related to the gas or diesel engine you are removing until the conversion is up and running. This space does not have to be in the same place as the car and workbench, just close enough to be convenient. The reason for not disposing of these parts as soon as they come off the car is that they are potential sources of brackets and hardware for the conversion.

Needless to say, your work and storage spaces should be secure and weather-tight, and the work space should be heated if necessary. The most important thing about the work space is that it is available for the full time necessary to finish the conversion. I work out of a one-car stall. I have occasionally had to strike the set in the middle of the conversion process and push a car out because I needed the space for a class or for some other reason. Doing this is extra work and very disruptive.

One of our customers was faced with the no-work-space-at-home problem. He rented a stall in a repair shop near his job to build his conversion. He worked on it during his lunch break and after work. Since the shop specialized in his make of car, he had access to special tools and advice. He could also pay the shop to do some of the work that he could not do or didn't want to do. The work space issue is a big one, but with a lot of determination and an equal amount of ingenuity, it can be solved.

### Tools

The number and kinds of tools needed to do a conversion fall somewhere between the collection found in your kitchen junk drawer and the full set of hand tools and numerous special tools found in a professional mechanic's toolbox. If you are an automotive hobbyist or do your own repairs and maintenance, you probably have most of what you will need already.

### Floor Tools

During the conversion process, the car spends a lot of time in the air with the wheels off. To get it there, you need a floor jack. By this I mean a fairly small wheeled jack like those used by mechanics to lift one corner or end of a car. It rolls around on steel wheels, and should have the capacity to lift 2 1/2 tons (2,280 kg) or more, at

**Mike Brown, using the right tool for the job.**

least 20 inches (50 cm). Even a small, light conversion will probably weigh 1 1/2 tons (1,370 kg) by the time you get the batteries in it. Something like a Chevy S10 pickup will weigh more. You want your lifting device to have more capacity than you need. "Just enough" isn't enough to be safe.

Once you have the car in the air, you need jack stands to keep it there. *(Note: Never work under a car that is only supported by a jack!)* These stands should have at least 3 to 6 tons capacity, be made of heavy steel plate, and have a minimum full height of 24 inches (60 cm). Buy your own jack and stands. Considering the amount of time you will be using them for the conversion, buying them is more cost effective than renting. Also, you should have a set in case you need to do any service or troubleshooting later that requires lifting the car.

Another floor tool needed is a comfort item: a creeper to lie on while working under the car. Concrete floors are cold, and crawling around under a car on your back gets old fast. Buy this tool also.

The last floor tool you will need is an engine hoist to lift the old gas or diesel engine out of the car and install the electric motor. Since it is only used twice in the conversion process, and the times it is used can be planned and prepared for in advance, this tool can be rented when it is actually needed. Unless, of course, you have a neighbor or friend who already has one. Be sure to get the chain or equalizer bar that attaches the engine or motor to the hoist.

Use the right tool for the job, especially a job this serious. I strongly recommend against lifting the engine out of a car using a garage rafter, tree branch, or the kids' swing set. They weren't made for the job, and you could get hurt.

**Power Tools**

An electric drill with a 3/8 inch (9 mm) capacity chuck is essential, and you should own one already. A 1/2 inch (13 mm) capacity drill might see limited use, and could be rented or borrowed from someone you know who has a serious tool habit. The same rent-or-borrow plan applies to a metal cutting saw like a jigsaw or Milwaukee Sawzall used for cutting holes in the chassis for battery racks. A 4 inch hand grinder is very handy for clearancing and finishing operations. You might want to own one of these, since they have a lot of house and yard uses. ("Clearancing" is a technical term. It means "beat or grind on it until it fits.")

**Hand Tools**

It's hard to say just what hand tools you will need. There are some that get constant use, and some that just seem to live in the bottom of the toolbox. A basic combination end wrench set in metric or inch sizes, whichever fits your make of car, is a good place to start. A 3/8 inch drive socket set with a ratchet and two or three different length extensions is also a necessity.

Another essential tool for electric vehicle work is an auto-ranging digital multimeter. An assortment of straight and crosspoint screwdrivers, wire cutters, wire strippers, a good ball peen hammer, a 24 inch pry bar, a hacksaw, a full drill bit index from 1/16 to 1/2 inch by 1/32 inch steps, a torque wrench, a pop rivet tool, measuring devices, straight edges, and large and small squares is a good start. This list could go on for quite a while. See our manual, *Convert It,* for a detailed list.

**Paper Goods**

Besides our step-by-step manual, there are two other books you will need for a successful conversion project. The first is the *factory* service manual for the car you are converting. This is the manual that the mechanics in the dealerships use. It has the correct ways to perform operations, such as where to put your jack stands to not damage the car, and how to remove the engine. It is also the source of tightening torque values, wear limits on parts, and most important of all, wiring diagrams for the car's 12 volt electrical system.

If the factory manual is not available or too expensive (the Porsche 914 manual is three volumes and costs over US$300), look for manuals put out by either the Haynes Publishing Group or Robert Bentley Publishers. These can be found at auto parts stores that cater to the local repair shops. Local bookstores might be able to order them for you. If local sources fail and you are online, give Amazon.com a try. They list quite a few Bentley manuals and could possibly special order the Haynes manual you need, since they carry some Haynes motorcycle manuals.

The other book you need is a project notebook. This book can be a spiral notebook, three-ring binder, blank bound book, or any other format you are comfortable with. It is where you note changes made in the car as the conversion progresses, make drawings of the parts you have to fabricate, draw wiring diagrams of the interface between the EV control system and the car's original 12 volt system, and draw the high voltage, high current cable layout. Do this in a regular, organized, and legible manner. Then you will be writing the factory manual for your conversion—for you or someone else to use at a later date.

**Knowledge & Experience**

It is difficult to say how much knowledge and what kind of experience is necessary to do a conversion. We have had people ranging from professional mechanics

to a high school student and his mother build successful conversions.

The type of conversion being built has an effect on the knowledge and experience needed. A bolt-in custom kit with detailed instructions requires only the ability to read and follow directions. If you are doing a conversion that needs design and fabrication of key components such as motor mounts, battery boxes and racks, and other component mounts, the amount of knowledge and experience required goes up.

Here's what has worked for me. When I find myself beyond my level of expertise, I try to learn as much as I can about the process and materials involved, so I am at least familiar with the terms used. Then I take my problems or project to an expert in the field, and get him or her involved. It may be necessary to pay for this initial consultation. If it is, pay cheerfully. Somewhere down the line, he or she paid for that knowledge with money, time, or sweat.

This person can help you design your needed part so it is strong enough to do the job, doesn't impose any weight penalty on the EV, and can be made easily to save fabrication costs. A word of warning: pick your expert with care. For example, since you are dealing with a car, picking a welder who works on race cars would be a better choice than a welder who builds gates, railings, or other architectural parts.

For the electrical part of the conversion, finding someone to help might be a little more difficult. If there is a local chapter of the Electric Auto Association or another electric car club, find out when its meetings are and attend one. This is one of the best sources of conversion information available because some of the members have "been there and done that" already.

Check with your local high school or junior college and see if they have done a conversion as a class project. The project may be finished, but the knowledge is still there. Your EV component suppliers should have given you at least basic component instructions and hook-up diagrams. If you have the *Convert It* manual, look at the chapter devoted to wiring both the high and low voltage systems.

The knowledge is out there if you look for it. When you find your experts, respect their knowledge. Be careful not to take up any more time than you need to, and pay them what they ask. And if they've gone out of their way to be helpful, a bag of chocolate chip cookies or donuts is almost always appreciated.

If the question we have been discussing here is one you have been asking, and I didn't quite answer it all the way, feel free to contact me by phone, mail, or email. I'll see if I can help you find the answers you need.

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*Convert It: A Step-By-Step Manual For Converting An Internal Combustion Vehicle To Electric Power,* written and published by Mike Brown and Shari Prange, is available from Electro Automotive for US$30 postpaid in the U.S. & Canada, and US$35 postpaid elsewhere. A full description of the book can be found at www.electroauto.com/info.html

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# Wŏrd Pow´ẽr

## Renewable Energy Terms

## Ohm—Unit of Electrical Resistance

Ian Woofenden



*Derivation: Named for Georg Simon Ohm, 19th century German physicist and mathematician. Ohm made key discoveries about the nature of electrical resistance.*

Picture some kids sliding down a playground slide. If we cover the slide with a thin coat of vegetable oil, the kids will slide down it pretty quickly. But if we cover it with molasses (in January), their ride will slow down considerably. Throw sand on the molasses, and the sliding party will come to a grinding halt.

We usually don't see kids' slides covered with oil, molasses, or sand. They are generally made with slick plastic or metal surfaces so kids will slip down them easily. Similarly, we don't see electrical conductors made out of wood or rubber. Instead, they are copper and aluminum. This is because wood and rubber have a very high resistance to electron flow, while aluminum and copper have a relatively low resistance to electron flow.

The ohm is the unit that quantifies this resistance. Its symbol is the Greek letter Omega—Ω. Technically, 1 ohm is the resistance in a material in which an electrical potential ("pressure") of 1 volt causes 1 ampere to flow. Electrical resistance acts like friction to the flow of electrons through a material.

Well, just as our kids want a fast ride down the slide, we want our electrons to flow quickly and easily to our appliances. High resistance on the slide raises the tempers of the kids. High resistance in a wire raises the temperature—we lose energy as heat. If there is too much electron flow for the size of the wire, there may be enough heat to melt the insulation on the wire and start a fire.

Different conductors (materials which contain easily-moved electrons) have different levels of resistance. Aluminum has about 1.6 times the resistance of copper. It's cheaper than copper, but when we use it, we have to use a larger wire to carry the same amount of energy (at a given voltage) without increasing the losses. Steel has about 9 times the resistance of copper, so we don't see it being used as an electrical conductor. And nichrome, an alloy of nickel, iron, and chromium, has about 60 times the resistance of copper. It is used for heating elements because, while it does let electrons flow, its high resistance results in lots of heat.

Materials with very high resistances are called "insulators." Things like rubber, glass, and mica have more than a million times the resistance of a good conductor. We use this property of these materials to keep the electron flow where we want it—in the wires.

The size of conductors is also important in understanding resistance. Just as a big pipe has far less fluid friction than a small pipe, a larger wire resists the flow of electrons less than a small wire. A #14 (2 $mm^2$) copper wire, common in 120 VAC house wiring, has 2.57 ohms of resistance per 1,000 feet at 70°F. A #4/0 (107 $mm^2$) copper wire, commonly used for battery interconnects, has only 0.05 ohms of resistance per 1,000 feet at 70°F. Sizing for minimal losses in your wiring just makes good sense.

While you won't run into ohms very often in your everyday RE life, it's crucial that the designers of your system, and the designers of the products in your system, understand the need for low resistance. Renewable energy is precious, so it makes no sense to waste it heating up undersized wires. Investing in the right type and size of wire will keep those electrons sliding along to your appliances.

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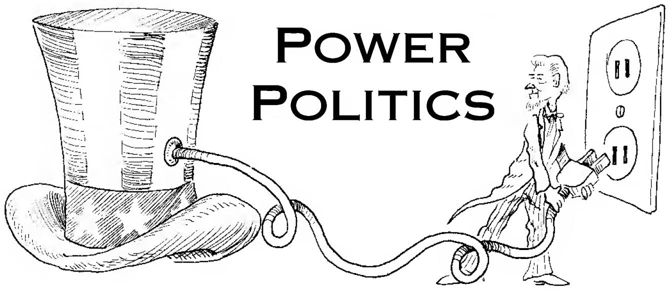



# Nuclear Junkets

Michael Welch



Yucca Mountain, Nevada is still the only site being considered as a repository for the high level nuclear waste from U.S. nuclear reactors. This fact is a testament to the power that the nuclear industry continues to wield over politicians and bureaucrats.

### Nevada Is Not a Wasteland

Most everyone will agree that there is no good solution to the problem of nuclear waste. But is Yucca Mountain the place to put it? Nevada was chosen as the repository site for more than 77,000 tons of the nation's most radioactive waste for several reasons. Chief among them is that the state is often thought of as a sparse expanse of emptiness. Last fall when we drove through hundreds of miles of its desert while coming back from the Southwest Renewable Energy Fair, it began to feel that way even to us.

But a commonly spied bumper sticker points out the reality of the situation—"Nevada Is Not a Wasteland." As with other hot and dry climates, Nevada deserts are teeming with wildlife and specialized plant life. Quick research of these unique biosystems will verify to anyone interested that the Nevada deserts are not "nothing." They are radically more sensitive to intrusion than climes that are more lush. Aerial photos of deserts still show vehicle corridors that are left from horse and wagon days. Living in the desert is not for me (I live in an area of Redwood-populated rainforest), but to many, Nevada's arid climate is just their cup of tea.

One key reason that Nevada's site has not been removed from consideration is political. Congress, presidential administrations, and agency bureaucrats thought that Nevada would not be able to muster enough political strength to fight having the dump foisted upon them.

But once the Yucca Mountain site was chosen, Nevada did not roll over. Nevadans, the Nevada state government, regional and national groups located in Nevada, and U.S. Senators and Representatives from Nevada all have proven to be worthy opponents of the dump siting. They have good reasons for their fight, with sound science to back them up.

### No Place for Long-Term Storage

Not only is the dump and its nuclear waste trucking unpalatable to Nevadans, it also does not meet the environmental standards that a long-term nuclear waste facility should have. It is going to leak, and it is a seismically active site. Those are facts, proven by extensive studies done by the very agencies that are preparing the site for receiving nuclear waste. The plan is to put barrels of nuclear waste into huge tunnels that have been bored deep into Yucca Mountain's rock core. It is known that no container can last even close to the amount of time that the nuclear waste will last. Once the containers have become breached, the radioactive gases (primarily carbon-14) from them will permeate the tunnels and end up in the environment.

Yucca Mountain contains a massive array of faults and fissures in its rock base. Water percolating into and through the repository tunnels will speed up the container failures, and also carry the radioactivity downward, eventually contaminating the water table. According to the Nuclear Information Resource Service (NIRS), this fast flow pathway was discovered because of fallout from the very industries that created the waste that would be sent to the site. Traces of chlorine-36 were found by DOE researchers deep in Yucca Mountain at the level where the waste would be dumped.

This radionuclide is not found at these concentrations in nature. There is only one bulk source of chlorine-36: atmospheric nuclear weapons tests conducted in the Pacific. Salt in the seawater was activated, forming the radioactive chlorine isotope. This "fell out" all over the northern hemisphere; it is not unique to Yucca Mountain. But its presence at repository depth proves that water has traveled there within the past 50 years.

These problems would have permanently sidelined Yucca Mountain as a repository had the original EPA standards been adhered to. But Congress ordered that the Yucca Mountain facility be exempt from radioactive

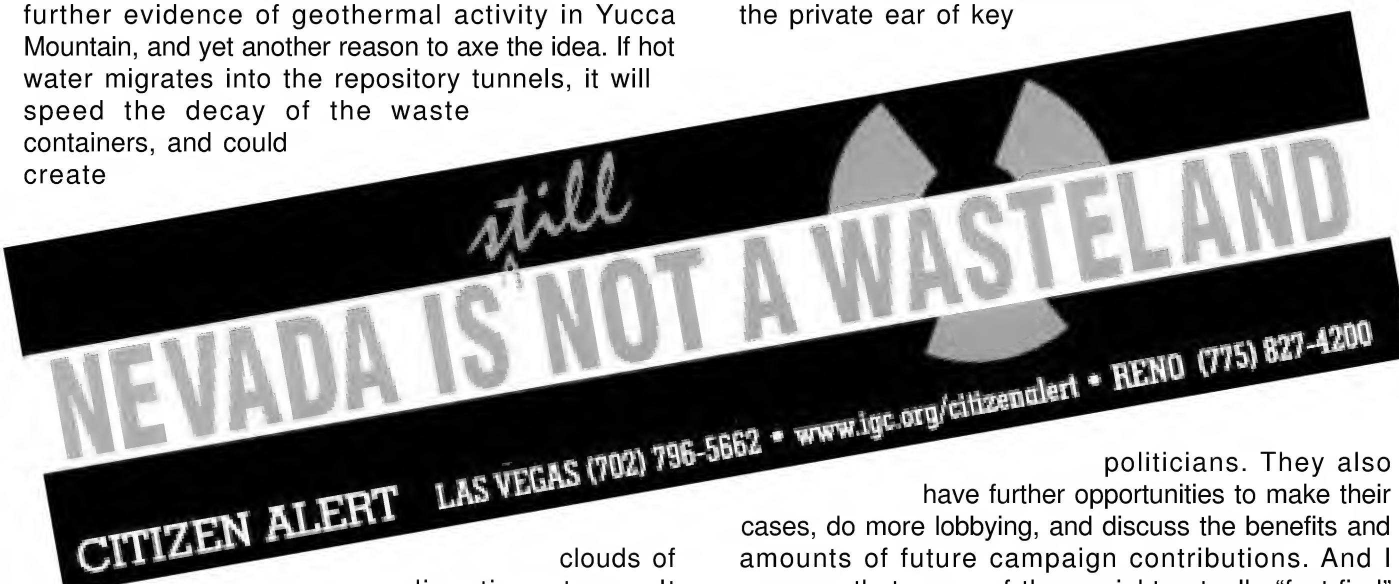
gas leakage standards in 1991, after it became clear that the existing standards would stop the siting.

The DOE's own data shows that water and whatever it contains migrates quickly through the rock via those fissures. In 1998, more than 200 environmental and public interest organizations sent a petition to the Secretary of Energy. They asked him to disqualify Yucca Mountain as a nuclear waste dump, since it clearly will fail to meet site suitability guidelines, and will not isolate nuclear waste. Instead of acting on this petition, the DOE is trying to change the guidelines so that the repository licensing can move forward.

Finally, the explosive news: crystals have been discovered in Yucca Mountain that could only have been formed in the presence of *hot* water. This is further evidence of geothermal activity in Yucca Mountain, and yet another reason to axe the idea. If hot water migrates into the repository tunnels, it will speed the decay of the waste containers, and could create clouds of radioactive steam. It could even create an explosion, either from the expanding steam, a chemical interaction, or a nuclear chain reaction.

Proponents of the Yucca Mountain repository have been working hard toward its opening since before it became the only site to be considered, in 1987. A project that only benefits a specific industry does not move forward without massive corporate influence. The proponents are almost all in the nuclear power and weapons industries. They want to turn the waste from their mostly privately-owned reactors over to publicly-owned facilities. Then they will no longer have to be concerned with the liabilities of that waste.

**Junkets**
I often decry the amount of influence non-renewable industries have over decision-makers who are supposed to be responsible to the public. I often talk about campaign contributions and lobbying efforts by these cash-rich corporations. There is yet a third form of backdoor politics that gives corporations a huge amount of influence over legislators—junkets. These are trips that are paid for by the companies and the industry associations that represent them.




Here's how it works. Politicians and their key staff are offered all-expenses-paid "fact-finding" trips. It is against the law for politicians to receive gifts of vacations and travel from outside of government. But trips to make speeches, attend conferences, and take site tours are allowed, even though they are paid for by special interests.

When politicians accept these junkets, they are taking legal bribes. Additionally, the companies and industry associations that pay for the trips get the private ear of key politicians. They also have further opportunities to make their cases, do more lobbying, and discuss the benefits and amounts of future campaign contributions. And I suppose that some of them might actually "fact-find" while on these junkets.

There are three key Congress members being watched as staunch proponents of the Nevada nuclear waste repository. They are Senators Frank Murkowski (R-AK) and Larry Craig (R-ID), and Representative Joe Barton (R-TX). Murkowski is the Senate Energy Committee chairman, Craig is a member of that committee, and Barton is chairman of the House Commerce Subcommittee on Energy. All of these are very powerful positions that deal with DOE matters.

According to a recent article by Benjamin Grove of the *Las Vegas Sun,* these three politicians and their staff have gone on 77 paid junkets for the nuclear power industry since 1996, totaling more than US$200,000 in paid expenses. The *Sun* found that these trips varied from low budget overnight trips to an approximately US$15,000 trip for Murkowski and his wife to visit Avignon, France for a week.

In 1997, special-interest groups paid about US$6.3 million on travel for Congressmembers and their staff. Murkowski's office was the #2 recipient with almost US$82,000, about 25 percent of which was paid for by the nuclear industry. Craig was #4 with almost US$43,000, 30 percent coming from the nuke industry. According to the article, in 1997 the Nuclear Energy Institute (NEI, the leading nuke industry lobbyist) paid for 98 junkets. In 1999, NEI spent US$1.6 million on lobbying both Republicans and Democrats. That can buy some real power.

Some folks might think, "Hey, what's the big deal—at least taxpayers aren't paying for the junkets." True, we might not being picking up the tab, but believe me, we pay for it big time—in loss of citizen access to *our* representatives. The same easy access that the nuke and fossil-fuel industries have to government is keeping the cash-poor RE industry at its too-slow rate of growth and acceptance. The democratic process suffers as a result.

Nuclear junket recipients counter that they need firsthand exposure to sites and the industry because the information is so technical in nature and site-specific. They say there is nothing quite like a site visit to get the full understanding of what is going on. They claim that the perks included with these trips (like golf games, five-star hotels, and lavish restaurants) are minor compared to the rest of the junket cost, and only offer them a little added enjoyment which is necessary when dealing with intense, technical issues. They say they aren't really swayed by such gifts, and that no extra influence is attained.

I say bull. If industries weren't getting what they want out of these trips, they wouldn't be spending corporate money on them. Many Congressmembers like and expect these perks, and actively seek them out. Maybe some day soon, this kind of corporate influence will be outlawed, or our fledgling RE industry will come of age and be able to exert its own cash influence. I'd rather the former than the latter, because energy isn't the only area where we are losing our democratic process.

**Meanwhile, Put Your Finger In the Dike**
Many activists believe that the Yucca Mountain facility will never be licensed. Count me among the hopeful, but I have nagging fears of what the industry and their paid politicians will be able to pull off. The draft environmental impact statement (DEIS) for the Yucca Mountain project will be subject to a series of public hearings starting in September (see Access).

Nevadans are gearing up an educational effort for this summer that will help prepare their communities for dealing with the DEIS. Then groups like Reno's Citizen Alert will take their educational show on the road for the rest of the nation. Support these folks (yeah, send them some bucks) and be sure to catch their show when it is near you. If we all act together, we can stop Yucca Mountain licensing in spite of industry influence.

**Late Breaking News**
As we went to press, President Clinton vetoed the legislation that would have allowed thousands of tons of radioactive waste to be shipped to Yucca Mountain (See *Power Politics, HP71 & 74).* Dump proponents are trying to gather enough votes to override the veto, starting with the Senate. So once again it has become important to call your Senators to let them know your feelings about this important issue.

**Access**
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Yucca Mountain Draft Environmental Impact Statement
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Schedule for Yucca Mountain DEIS Public Hearings
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Don Loweburg



# Solar Thermal—Another Look

Solar water heating is underutilized. Many remember the horror stories about systems installed in the mid 1970s and early '80s during the tax credit era. There were problems. Some were because of poor design and installation, while others were due to premature failure brought on by a lack of regular maintenance. With the end of tax credits, many companies went out of business, and their customers were left unsupported.

Another setback was the fact that energy prices did not escalate as some had anticipated. So, should we conclude that solar thermal is a bad deal—a failed technology? On the contrary, solar water heating should be one of the first options implemented globally in the shift from carbon polluting energy sources to renewable energy sources. Why isn't this happening?

**High Cost?**

Some argue that a major problem with solar water heating is the high cost of the technology compared to its economic payback. The payback economics are variable. Factors involve backup choice (electric, natural gas, etc.), geographic location, the amount of hot water produced per day, and the particular technology choice for the solar collectors. However, when the economics are based on life cycle cost, there will be an overall economic savings with solar hot water compared to not using solar. The failure here is that the economic system and current building practices do not reward good design and life cycle costing. But this is only part of the story.

There is another, institutional problem. In this country, a great deal of attention and discussion is focused on *electrical* energy generation. Electricity deregulation, distributed generation, restructuring, and renewable electric generation have captured the attention of progressive policy planners. Though meager, we are seeing some incentives for renewable electrical energy generation—wind, PV, and biomass, for example. Yet many of these programs offer nothing for solar thermal!

**BTUs Are Energy**

This ignore-ance is based on a prevailing institutional view that solar thermal is a load reduction/load management technology. This is incorrect. Solar thermal collectors are a generation technology. The confusion is based on the fact that they produce BTUs (British thermal units—heat) rather than moving electrons. Policy designers seem to miss what any first semester physics student knows. Energy is energy, whether in the form of BTUs (heat) or moving electrons (electricity). All forms of non-polluting energy generation should be equally rewarded.

The fundamental value of renewables is that they capture available energy without any emissions. Carbon energy resources used to heat water will emit tons of $CO_2$ over the life of the system. These emissions are presently not accounted for economically. But the cost is very real. $CO_2$ is pollution. Shouldn't polluters pay to mitigate the damage they produce?

Those who argue against $CO_2$ pollution regulation are no different than folks who argue that they should be allowed to throw garbage in the alley or along the roadside. Most of us would have big problems with the latter. If non-polluting technologies like solar water heating were rewarded for avoided environmental damage, there would be a lot more solar water heaters out there.

**We Have the Data**

The *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1997* is published by the EPA, and is available to the public. ("Sinks" are green growing things, everything from trees to algae, which take $CO_2$ out of the atmosphere and "fix" it back to a usable energy source.) This compilation is a rich source of

data presented from different perspectives. Here are some of the key findings:

- The largest source of $CO_2$ and of overall greenhouse gas pollution in the United States is fossil fuel combustion (81% and increasing).
- The overall effects of carbon combustion are becoming very clear. From 1750 to the present time, global $CO_2$ levels in the atmosphere have risen 28 percent.
- As a consequence of the greenhouse effect, the average global temperature has increased about one degree Fahrenheit.
- Two major human activities in the United States are responsible for over half of the total carbon pollution. Transportation activities account for 30 percent of $CO_2$ pollution, and utility electric generation contributes 36 percent.

The utility component bears special attention. Though utilities produce 36 percent of the pollution, they only produce 28 percent of the national energy. This apparent incongruity occurs because utilities rely on coal, the most polluting source of energy (next to nuclear), for over half of their total energy requirements. Because utility power is the source of a disproportionate share of $CO_2$ pollution, replacing utility generation with non-polluting renewable generation should be a priority.

**Electrical Efficiency Must Improve**

Renewable energy generation is only part of the big picture. Just as important as non-polluting generation technologies are the ways that energy is used (and wasted). Efficiency improvements in motors, compressors, and lighting have been available for many years. Using off-the-shelf technology, residential energy use per capita in the United States could be reduced 50 percent by relying on efficiency improvements.

I base this conclusion on my twenty years of living off-grid. Our home and business operate on about 9 KWH per day, and we enjoy a very comfortable lifestyle. The point is not that everyone should live off-grid, but rather that the off-grid experience has provided a laboratory to demonstrate and prove what is possible using readily available energy efficiency measures.

**For More Information**

Ray Darby is an energy professional and activist in California. We met at a meeting in Sacramento, California a few months ago. Our conversation touched on many of the points above, and he mentioned that he maintains a personal Web site. I've visited the site, and I think it should get a plug (www.theenergyguy.com).

Ray's site does not have an institutional or bureaucratic affiliation. Ray has a point of view, but invites people to visit the numerous links and resources and make up their own minds. There are many links, including those listing appliance efficiency. Visitors looking for PV links may be disappointed, since the site's emphasis is on efficiency. I don't have a problem with this. Efficiency and renewable generation are complementary solutions to global carbon pollution.

**California PV Rebate**

The California PV rebate program has paid over US$3,000,000 to California homeowners and businesses. In the process, the program has encouraged the installation of over 255 PV systems, with a total electrical output of over 1.5 megawatts. The California Energy Commission manages the Emerging Renewables Trust Fund, which has enough funding available for several years.

In addition to putting PV on rooftops and reducing carbon pollution, the program's goal is to improve the quality of installed systems. Several program requirements achieve this. System output in AC watts is rewarded, rather than the inflated DC module output watts (measured at an unrealistic 70°F). Also, components and installation must be warranted for five years. Though modules generally have no problems qualifying, inverters—which typically have only a two year warranty—don't yet make the grade.

This creates a dilemma for system installers who are either providing extended warranties out of their own pockets, or charging the customer for factory extended warranties and pushing up the price of the system. It is time inverter manufacturers stepped up and offered a standard five year warranty. The first to do so will certainly get my business. Finally, installed system quality is maintained by a local inspection requirement and by the commission's own quality assurance program, which spot checks installed systems randomly.

**Buying & Selling PV**

Responsible dealer-installers have been searching for ways to serve new customers while competing with the direct sales "big box" type outlets. Installing dealers know the value of what they offer, but often the potential customer may not be very well informed. An installer may get calls for a price quote on a system, but the potential customer does not know what is needed. In essence, the caller is asking for a parts list (de facto design) with pricing. Sometimes a potential customer calls with a price on an inverter and panels, wanting a better price. During the conversation, it becomes

evident that the caller thinks these components are all that is needed for a solar-electric system.

Most often the callers are not fully informed of the complexities of an installed PV system. Maybe they are new readers of *Home Power,* and haven't had time to digest the wealth of good design and technical information available. But they have scanned the many ads for RE gear and systems. Having some "best" pricing in hand from one of the low-ball parts marts, the shopper calls around.

Often the discount outlets offer free design, unlimited customer support and wiring diagrams, all included at no extra cost. When such a potential customer talks to a full service dealer, there is often a breakdown. The breakdown must be understood from the perspective of the customer.

The customer may not fully know the difference between boxes of components drop shipped on their doorstep and a well-designed and complete PV system. Remember, those whose mission it is to push product will emphasize how easy and simple it is to set up a solar-electric system. The customer may not be aware of the difference between a real custom design and a boilerplate diagram that anyone with a computer or copy machine can crank out.

Potential customers can't value what they don't know. Those of us with a knowledge base of installed systems, and the expertise that comes with that experience, need to kindly communicate these facts. Most people are intelligent enough to know that you get what you pay for.

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**The Devil in the Details**

Distributed generation (DG) in its broadest scope includes almost all non-centrally located generation. The degree of distribution can be quite variable. A PV panel on an off-grid yurt and a gasoline generator in the back of a pickup truck both qualify as DG. A wind farm may be quite large compared to the needs of a home or business, but can still be considered small (distributed) from the point of view of central utility generation.

Another significant variable in DG is fuel type. Though a gas-fired micro turbine may represent a significant improvement in efficiency and pollution when compared to central utility generation that uses coal as fuel, a gas-fired turbine still produces significant pollution when compared to renewable DG. All DG is not equal.

Last year the California Public Utilities Commission (CPUC) began hearings on DG. The proceeding titled *Order Instituting Rulemaking (OIR) 99-10-025* is intended to provide input to the commission so that they can address the special issues relevant to DG. Participants in this process include a wide variety of principals. These include utilities, independent generators, energy marketers, large commercial and industrial users, consumer advocates, environmental groups, and equipment manufacturers. Missing to date from this list are participants from the PV industry!

The Photovoltaic Distributed Power Coalition has been formed so that the interests of the PV community are incorporated into any rules and procedures the commission may create regarding DG. The coalition includes manufacturers, distributors, IPP, and CAL SEIA. The purpose of the coalition is to present before the CPUC these key attributes and needs of distributed photovoltaic generation:

- Remove onerous interconnection policies;
- Eliminate standby charges for PV systems;
- Extend the PV net metering law to larger commercial and industrial photovoltaic installations;
- Capture the economic benefits that distributed PV installations provide to the utility distribution, transmission, and power management systems;
- Curb business practices that enable utilities to discourage the deployment of distributed PV power;
- Remove or avoid regulatory practices that create barriers to the deployment of distributed power, such as exit fees, anti-bypass contracts, stranded cost charges, and various tariff restrictions.

Participating in these proceedings is costly. The coalition has retained representation by a person who not only understands the regulatory process from the inside, but is also conversant with PV and DG. To help us support this effort, IPP is asking for immediate donations. Members who have not paid dues lately, please do so—and kick in a little extra. Non-members who have a commitment to PV and understand what's at stake and the potential benefits, please support this project. Any amount is welcome, but please send something that is commensurate with your commitment to PV and your pocketbook. If you have reservations, please be willing to stretch a bit from your present position.

This OIR proceeding is important not only in California. If a favorable regulatory context is created in California, it will have influence in other states. If you think that off-grid PV is the only cost-effective application worthy of support, consider the cost reductions in PV taking place with grid penetration. Certainly everyone benefits. There are no "proper" applications for PV. We want to see it everywhere. Please make your checks payable to IPP, with the memo "OIR."

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Order Instituting Rulemaking (OIR), making new rules for DG

# Where To Use Which Conductor

John Wiles

Sponsored by the Photovoltaic Systems Assistance Center, Sandia National Laboratories

There are always questions about exactly which cable types can be used in each of the various locations in a PV system. This *Code Corner* will build on the information presented in my last column, and look at each part of a PV system with respect to the types of cables that might be allowed under the *National Electrical Code (NEC).*

**PV Module Interconnections**

Let's start at the PV module, where the electrical energy originates. PV modules get hot when they operate. Module junction box temperatures above 70°C (158°F) have been measured. The modules are also in exposed outdoor locations. Junction boxes have been found filled with water, even days after the last rain. With these things in mind, you can see why the *NEC* requires PV wiring to be rated for use in wet and high temperature environments. In fact, the code requires any wiring that will be exposed, or installed in conduit in exposed or underground locations to be wet rated.

The *NEC* permits module wiring to consist of single-conductor exposed cables between the module junction boxes and any array-mounted combiner/overcurrent box or array-mounted disconnect box. This allowance for exposed single-conductor PV module wiring is one of the very few places in the code where such wiring is allowed. In fact, local codes—particularly codes involving commercial and not residential installations—may prohibit such exposed conductors.

One of the best conductor types that meets the temperature and moisture requirements for this exposed PV module wiring is type USE-2. See *Code Corner, HP76,* for a description of this and other cables. Type USE cable is only rated for 75°C (167°F), and is not suitable for this application unless installed in areas where ambient temperatures stay below about 30°C (86°F). Type SE cable may also be used when it has an insulation rated for 90°C (194°F). Note that some types of SE cable have only 75°C (167°F) insulation—the rating will be marked on the cable. Although the code mentions type UF cable, this cable generally has only a 60°C (140°F) or 75°C (167°F) rating, which is not adequate for most module wiring.

The *NEC* also generally allows any other wiring method covered in the code to be used for module wiring. For example, type TC cable as a single-conductor exposed cable or as a two-conductor jacketed cable may be used when marked sunlight resistant. Other types of conductors may also be used if installed in conduit for physical and ultraviolet (UV) protection. Commonly available conductor types that can be installed in conduit and that are suitable for module wiring are THWN-2, THW-2, RHW-2, and XHHW-2.

Some of these cables may have additional markings such as the dual-marked THWN-2/THHN and USE-2/RHW-2. In these cases, the cable takes on the properties of each type, and the most strenuous rating can be used. Cables that do not have any of the markings listed in the previous paragraph should not be used. For example, a common type THHN conductor with no other type markings is not suitable for use in conduit for PV module wiring.

Note: A conductor marked with only type USE or USE-2 may not be installed in conduit inside buildings because it does not have the necessary flame retardant. In many cases, these USE-2 cables are also dual marked with type RHW-2, and type USE cable is accompanied by the RHW type marking. These dual-marked cables are suitable for use as exposed single-conductor cables and as cables inside conduits in buildings.

**Wiring In Conduit**

If conduit is used for module wiring, it should be electrical conduit. Such conduit comes in several rigid, flexible, metallic, and nonmetallic styles. Each style has matching fittings and/or cements that must be used. Plumbing PVC conduit is not allowed, nor is plumbing PVC cement to be used to cement electrical nonmetallic conduit.

Standard galvanized plumbing pipe and pipe fittings should not be substituted for rigid electrical conduit and electrical conduit fittings even though they are the same size. Threads and manufacturing methods are different for each. When using flexible nonmetallic conduit, the three-piece compression fittings should be used instead of the one-piece fittings. The one-piece fittings are only listed for 60°C (140°F) and there have been reports of them coming loose in PV installations.

**Wiring Between PV Array & PV Disconnect**
The wiring from the PV combiner/overcurrent box to the PV disconnect and charge controller located some distance away should use one of the other wiring methods allowed by the code for all electrical systems (not the exposed single-conductor cables allowed by Article 690). Conductors exposed to outdoor environments must either be in conduit or of a cable type listed for outdoor environments (such as type UF). Outdoor wiring systems include conductors installed in conduits as described above, sheathed (jacketed) multi-conductor tray cable (when installed in cable trays or other approved raceways), and sheathed multiconductor UF cable (where the 60°C (140°F) temperature limitations can be met).

Several less commonly used and available cable types described in the *NEC* may also be used in some situations, but they usually are more difficult to obtain and install. These include armored cable, electrical nonmetallic tubing, metal clad cable, and others.

When the wiring is run through indoor areas, several wiring methods may be used. Conductors in conduit are also appropriate in this area. In this case, the conduits are not exposed to wet, outdoor conditions and there are more conductor types allowed. In addition to the conductor types mentioned above, the following types are allowed in conduit: THHN, THWN, THW, THH, RHH, TW, XHHW, and XHH. Some of these conductors and type NM, nonmetallic sheathed cable, have only 60°C (140°C) temperature rating, which would preclude their use in hot attics. Type UF sheathed cables may also be used indoors. Each of these wiring methods has specific installation requirements detailed in the *NEC.*

**Power Center/Battery/Inverter Wiring**
Wiring between the battery and the inverter, power center, and charge controller is usually heavier than other wiring in the system. To meet *NEC* requirements, this wiring usually consists of single conductors installed in conduit for physical protection. In some cases, large-gauge type NM sheathed cable may be used where it has the physical protection required by the *NEC.*

The normal stranding for conductors in the #1/0 to #4/0 (53–107 $mm^2$) size range is seven to thirteen strands per conductor. This stranding makes for a pretty stiff conductor. However, all listed electrical equipment has sufficient wire bending room to deal with this cable, and commercial and industrial electricians routinely handle these and larger sized conductors without problems. PV installers who prefer not to deal with these stiff conductors may purchase flexible conductors at an added cost from PV and electrical equipment distributors. Types RHW and THW are usually available in high-stranded flexible versions.

**Equipment-Grounding Conductors**
Conductors used for equipment grounding may be bare (without insulation) or have green-colored insulation. If insulated conductors are used, the type of conductor must comply with the guidelines discussed above. Uninsulated conductors used as equipment-grounding conductors have no temperature or moisture limitations; however, they must be installed so that they meet code requirements for such conductors. Generally, these conductors must be run with the circuit conductors, and will therefore be run in conduit or manufactured as one of the conductors in a sheathed cable.

**Summary**
The PV designer/installer has a wide variety of conductors and wiring methods to choose from. Each method has advantages and restrictions. A thorough knowledge of the requirements in the *National Electrical Code* will provide insights that will enable safe, cost-effective PV systems to be installed.

If you have questions about the *NEC* or the implementation of PV systems following the requirements of the *NEC*, feel free to call, fax, email, or write me. Sandia National Laboratories sponsors my activities in this area as a support function to the PV industry. This work was supported by the United States Department of Energy under Contract DE-AC04-94AL8500. Sandia is a multi-program laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy.

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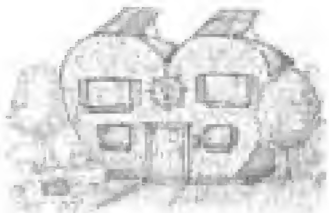
# Home & Heart



Kathleen Jarschke-Schultze



At the end of last summer, I was introduced to a new production model solar cooker. It is made to cook efficiently in the summer, and also in the winter, when the sun is lower in our sky.

**The Sunlight Cooker**

The Sunlight Cooker came to me in a custom-made corrugated cardboard shipping box. It was well protected from dings and dents. The boxed unit was light enough that I had no problem carrying it.

There are three different models of the Sunlight Cooker. The Small is 16 by 13 by 13 inches, with the inside area 10.5 by 9.5 by 4.5 inches deep, sloping to 9.5 inches in back. It costs US$239. The Medium is 19 by 15 by 16 inches, with the inside area 15 by 12.5 by 4.5 inches deep, sloping to 11.5 inches in back. It costs US$279. The Large is 24 by 18 by 20 inches, with the inside area 19.5 by 17 by 4.5 inches deep, sloping to 13.5 inches in back. Its price is US$349. I have the Medium model.

The cooker is a multiple-reflector style. This style is sometimes called the 30°/60° cooker. It was patented and popularized by solar pioneer Dan Halacy in the 1970s. The makers of the Sunlight Cooker worked with the Halacys many years ago. This cooker is made so that two different sides can become the bottom of the cooker, resulting in a choice of two different glass angles, 30 or 60 degrees. This allows the cooker to focus when the sun is either high or low in the sky.

The polished aluminum reflectors fold out easily and set up quickly. It takes me less than one minute to unfold and position the cooker for use. There are four main reflectors (top, bottom, right, and left). The right and left reflectors each have two additional wedge-shaped, piano-hinged reflectors attached to their sides. These slip into slots on the main reflectors, and are secured with Velcro tape on the non-reflective side. When folded for moving or storage, the hook-and-loop tape secures the reflectors closed on the unit. There is also a sturdy handle on the shortest side for easy carrying.

The oven box is made of 3/8 inch plywood covered with marine canvas. The material is used for many marine applications, and is UV and water resistant. With 1 1/2 inches of oven-type insulation, there is no danger of outgassing. The interior of the cooker is sheathed in sheet metal painted with high temperature flat black paint.

The wood-framed, glazed door is plate glass with a secure leather tab for a handle. If the inside paint is scratched or rubbed off, it is easily repainted. Since the door glazing is plate glass, it is also easily replaced if damaged.

There is an ingenious focusing target drawn on the outside of the cooking box. It corresponds with a small hole cut into one reflector. When the sunlight comes through the hole and hits the direct center of the target, the cooker is in perfect focus.

**Performance**

I've used the Sunlight Cooker in winter and in summer, and I'm excited by its performance. It is sturdy and stable in a wind. This is an important point for me, since we live in a canyon with a mountain at one end and a lake at the other. The cooler upper air and warmer lower air act like a thermal flywheel. In short, the canyon is usually windy. Winter also brings shorter daylight hours in our canyon. I was able to utilize the 30°/60° feature of the cooker to my great satisfaction.

I have cooked the usual array of chickens, roasts, casseroles, and breads. I've found the Sunlight Cooker

**Kathleen's medium sized Sunlight Cooker.**

to be efficient, effective, and easy to use. No matter what the ambient temperature, if it's sunny, the Sunlight Cooker cooks. It takes about twenty minutes to preheat the cooker to 350°F. The temperature goes down some when I put the food in, but it rises again as it cooks.

In the winter, I did tend the cooker more carefully. I refocused the cooker about every hour, being careful to set it up so that the sun was always moving into focus, therefore getting hotter, not leaving full focus and getting cooler. We did not have much snow this year, so I never did cook in the snow.

This is a really swell solar cooker. It is easy to use and store, portable for long or short distances, and big enough to cook a family's meals. I really enjoy using the Sunlight Cooker. It is very well made and will last a long time. I feel it is well worth the price. The manufacturer has a great Web site with more pictures, and other products and background.

**Accidental Cookware**

Quite by accident I discovered some unique and effective solar cookware. My friend Lynne had given me a two quart heat-proof glass measuring bowl. It immediately became my favorite bowl. I use it for everything. It's big, it pours, it microwaves, it's easy to clean, it has a handle—I love it.

I could probably get rid of half of my mixing bowls now because I never use them. This would please Bob-O. He says I have way too much cooking equipment. I argue that these things are *my* tools. You have to have the right tool for the right job. I don't go through his tool box (heaven forbid!) and tell him he should get rid of two of the four 1/2 inch box-end wrenches he has. I haven't let any bowls go yet—I might need them.

April Fool's day was sunny and clear—perfect conditions to roast a whole chicken in the Sunlight Cooker. I had mixed up a marinade of sesame oil, White Zinfandel wine, Bragg Liquid Amino, black pepper, and garlic. I had the chicken and marinade in the two quart measuring bowl. When I wanted to pour the marinade over the chicken, all I had to do was hold the chicken in the bowl with a wooden spoon, pour the marinade into a small canning jar, and repour the marinade over the chicken. Short and sweet.

I was then struck by a scathingly brilliant idea. If I covered the top of the measuring bowl with microwave-proof plastic wrap, I could just roast the chicken in the bowl! By using the same method I used to marinade, I could easily baste the cooking chicken. Voila! Victory! Success!

Now I can mix and bake in the same bowl. I need another two-quart model, and a one-quart model of these heat-proof glass measuring bowls. There are several brands available. Heat-proof glass measuring cups and bowls are sold all over. It is a common retail item in any cookware store and in a lot of other non-specialty stores.

Another type of glass solar cookware I have been using for years is Visionware. So I knew about the effectiveness of cooking in glass, tinted or clear. Visionware has the added attraction of having lids. I have used the amber and cranberry Visionware with equal success.

**Just Solar Cook It!**

Solar cooking season is here. Get out and do it! Experiment with recipes and cookware. Make your family a solar-cooked meal. It will turn out delicious more often than not. You'll be surprised at how easy it is.

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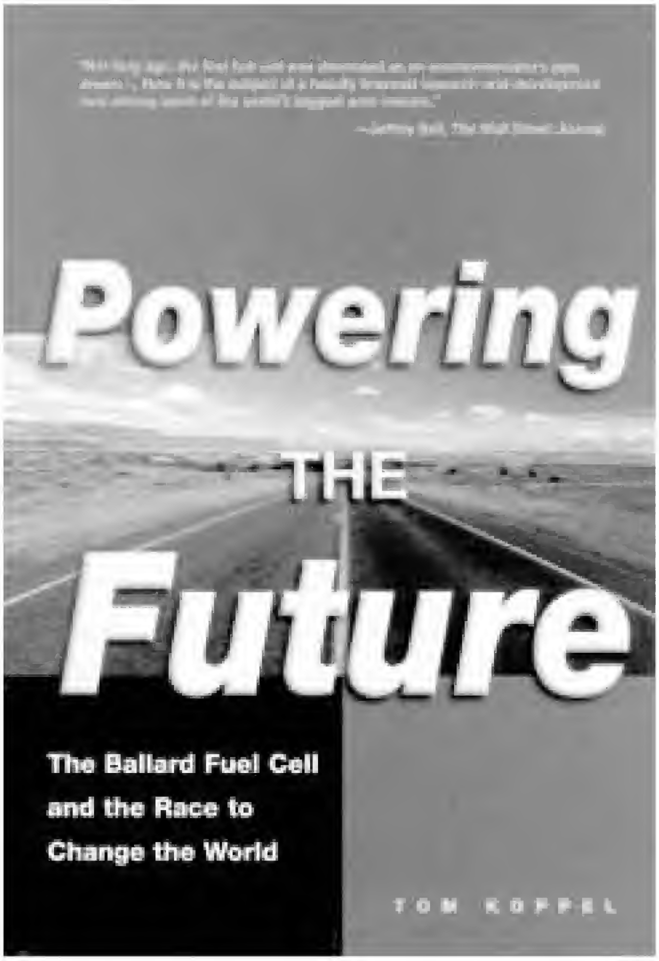


By Tom Koppel

Reviewed by Richard Engel



For supporters of renewable energy who want to see sustainable technologies enter the mainstream, the past couple of decades have been a roller coaster of hopes and frustrations. Tax credits come and go, stock values for RE companies rise and fall, and government and industry continue to struggle over target dates for zero-emission vehicles to arrive in showrooms.

Only in recent years have we begun to see what looks like a steady, long-term climb out of the fossil fuel sinkhole up toward higher ground, where everyone will have access to affordable renewables. Ballard Power Systems has proven to be one of the leaders in pushing and pulling non-polluting energy technologies toward the mainstream. Tom Koppel's new book tells the engaging, sometimes turbulent story of how Ballard attained that front-runner status.

**From Batteries to Fuel Cells**

Ballard started out working on advanced lithium batteries. But they soon changed their focus to hydrogen fuel cells, particularly for transportation applications, and that's where they've made their mark. A fuel cell works much like a battery. But rather than charging and discharging its electrolyte, it produces constant electrical output as hydrogen and air are continuously supplied. The only emissions are pure water. While there are many kinds of fuel cells, Ballard's technology of choice is the proton exchange membrane (PEM) fuel cell. Its compact size, low operating temperature, and quick startup make it the best choice for automotive and many other applications.

Koppel does give some background on the technical aspects of PEM fuel cells, but this isn't a nuts and bolts book. It's more of a biography, partially of company founder Geoffrey Ballard. But more broadly, it's the tale, both inspiring and cautionary, of how a small, focused business got quite big, making some people rich along the way, but also losing some of that visionary focus.

There was a point in Ballard's growth when Geoffrey Ballard and his team realized that they couldn't compete directly with Detroit to bring the world the technology that may someday soon replace the internal combustion engine. Their solution was to seek a partnership. So they explored this possibility with several auto manufacturers in Detroit and overseas. They ended up linking with DaimlerChrysler, which now owns a large portion of Ballard.

**Bumpy Roads**

As a fan of "small is beautiful" precepts, I found one of the central messages of this book a bit hard to swallow: that a small company's inevitable reward for excellence is to become huge. The author concedes that Ballard's rapid growth (their stock value increased tenfold in three years) has made the company somewhat bureaucratic and inefficient. But perhaps this is a built-in tradeoff that comes with bringing green products to the mass marketplace.

Ballard's road to success was bumpy at times, as the company grew from its start in a "fleabag Arizona motel" to multibillion-dollar status. Koppel doesn't gloss over the personality conflicts and internecine struggles that were part of this evolution. I would have liked less emphasis on this side of the company story, though. It became a little tiresome to read about company leaders

getting along like "two scorpions in a bottle" when I could have been learning more about what was going on in the lab or out on the test track.

**Good Ideas Succeed**

The greatest strength of *Powering the Future* lies in its clear, optimistic tone. This book should make inspiring bedtime reading for small-time entrepreneurs who need affirmation that good ideas can succeed in today's often irrational business environment. Likewise, I hope this book is finding its way to the nightstands of Fortune 500 CEOs, who might direct some of their corporate muscle toward integrating those same good ideas into their existing product lines.

If you pick up this book, stick with it to the end. I found the last two chapters to be the most interesting. They provide a thought-provoking discussion of how the fuel cell might ultimately fit into our energy future. There's also a balanced look at the various options for fuels we might use to run PEM fuel cells, including gaseous hydrogen, liquid hydrogen, and methanol. I came to this book hoping to learn more about technical and energy policy issues related to fuel cells. I found what I was looking for in these closing pages.

**Access**

*Powering The Future: The Ballard Fuel Cell and the Race to Change the World,* Tom Koppel, US$27.95; Cdn$34.95, ISBN 0-471-64421-8, 1999, John Wiley and Sons Canada, Ltd., 22 Worcester Rd., Etobicoke, ON M9W 1L1 Canada • 800-567-4797 or 416-236-4433 • Fax: 416-236-4448 pfurlong@wiley.com • www.wiley.com

Reviewed by:
Richard Engel, Schatz Energy Research Center, Arcata, CA 95521 • 707-826-4345 • Fax: 707-826-4347
rae7001@humboldt.edu • www.humboldt.edu/~serc

# HAPPENINGS

**INTERNATIONAL**
Free instructions, photos, drawings, specs to build solar cookers and water systems with local materials purchased with local currency. SUNSTOVE • www.sungravity.com

**CANADA**
Oct. 15–18, '00: International EV Symposium, Contact: EVS-17, 650-365-2802 • Fax: 650-365-2687 ElectricEVent17@aol.com

Alberta Sustainable House: Open 3rd & 4th Saturdays, 1–4 PM, free. Cold-climate features/products re: health, environment, conservation, AE, recycling, low energy, self-sufficiency, appropriate technology, & autonomous & sustainable housing, 9211 Scurfield Dr. NW, Calgary, AB T3L 1V9 Canada • 403-239-1882 • Fax: 403-547-2671 jdo@ucalgary.ca • www.ucalgary.ca/~jdo

The Institute for Bioregional Studies demonstrates & teaches ecologically-oriented, scientific, social, & technological achievements. IBS, 393 University Ave., Charlottetown, PEI C1A 4N4 Canada 902-892-9578

Vancouver Electric Vehicle Association, call for meetings: PO Box 3456, 349 West Georgia, Vancouver, BC, V6B 3Y4 Canada 604-878-9500 • info@veva.bc.ca www.veva.bc.ca

**NICARAGUA**
Special short course on solar energy in Nicaragua. An opportunity to offer your hands, heart, and a unique gift: electricity! Nicaragua, Aug. 1–11, 2000 (repeated Jan. '01). Introduction to PV for developing countries, course offers lectures, field experience, and tourism. In English by Dr. Richard Komp and Professor Susan Kinne. $750 plus airfare. Contact Barbara Atkinson, lightstream@igc.org • 215-942-0184

**NATIONAL U.S.**
The National Environmental Trust's "Pollution Solutions Tour." Latest RE technologies including fuel cells, wind generators, solar water heaters, PV panels, efficient appliances, & alternative vehicles. 43 cities, 16 states. Remaining schedule: Minnesota: June 5, Duluth; June 7, Minneapolis; June 9, Rochester. South Dakota: June 12, Sioux Falls. Nebraska: June 14, Omaha/Council Bluffs. Iowa: June 16, Des Moines; June 19, Cedar Rapids. Illinois: June 21, Rock Island/Davenport. 888-887-8234 www.hotearth.org

American Wind Energy Association. Info about U.S. wind energy industry, membership, small turbine use, & more: www.awea.org

State financial & regulatory incentives for RE (reports). North Carolina Solar Center, Box 7401 NCSU, Raleigh, NC 27695 919-515-3480 • Fax: 919-515-5778 www.ncsc.ncsu.edu/dsire.htm

Energy Efficiency & Renewable Energy Clearinghouse (EREC): Insulation Basics (FS142), New Earth-Sheltered Houses (FS120), PV: Basic Design Principles & Components (FS231), Cooling Your Home Naturally (FS186), Automatic & Programmable Thermostats (FS215), & Small Wind Energy Systems for the Homeowner (FS135). EREC, PO Box 3048, Merrifield, VA 22116 • 800-363-3732 TTY: 800-273-2957 • energyinfo@delphi.com www.eren.doe.gov

Energy Efficiency & Renewable Energy Network (EREN), links to government & private internet sites & offers "Ask an Energy Expert" online questions to specialists: www.eren.doe.gov • 800-363-3732

Green Power Web site: includes deregulation, "green" electricity, technology, marketing, standards, environmental claims, & national and state policies. Global Environmental Options (GEO) & CREST: www.green-power.com

National Wind Technology Center, Golden, CO. Assisting wind turbine designers & manufacturers with development & fine tuning: 303-384-6900 • Fax: 303-384-6901

Tesla Engine Builders Assoc.: Info & networking. Send SASE to TEBA, 5464 N Port Washington Rd. #293, Milwaukee, WI 53217 • teba@execpc.com www.execpc.com/~teba

*Sandia's Web site, Stand-Alone Photovoltaic Systems: A Handbook of Recommended Design Practices, Working Safely with PV,* & balance-of-system technical briefs, info on battery & inverter testing: www.sandia.gov/pv

Solar Energy & Systems, Internet college course. Fundamentals of small RE. Weekly assignments reviewing texts, videos, WWW pages, & email Q&A. Mojave Community College • 800-678-3992 lizcaw@et.mohave.cc.az.us http://solarnmc.mohave.cc.az.us

Federal Trade Commission free pamphlets: *Buying An Energy-Smart Appliance, EnergyGuide to Major Home Appliances,* & *EnergyGuide to Home Heating & Cooling.* EnergyGuide, FTC, Rm 130, 6th St. & Pennsylvania Ave. NW, Washington, DC 20580 • 202-326-2222 • TTY: 202-9326-2502 www.ftc.gov

Solar curriculum for upper elementary & intermediate grades—Free! Six week science curriculum or individual sessions. Over 30 classroom presentations & demos using free or low-cost materials. Florida Solar Energy Center, Susan Schleith • 321-638-1017 www.fsec.ucf.edu

**ALABAMA**
The Self-Reliance Institute of NE Alabama seeks others interested in RE, earth-sheltered construction, & other self-reliant topics. SINA, 6585 Co Rd. 22, Centre, AL 35960 • cevans9@tds.com

**ARIZONA**
Living With the Sun lecture series by AZ Solar Energy Association. Topic: How to save money & the environment. Includes history & current overview of concepts, design, applications, & technologies on solar heating/cooling, architecture, landscaping, PV, & cooking. 7 to 9 PM. First Wed. of every month at Glendale Foothills Branch Library & third Tuesday of every month at Scottsdale Redevelopment & Urban Design Studio. Info: Jim Miller, 480-592-5416

Kyocera Solar Seminars. Advanced: June 13–15, Aug. 15–17. Technical training by professionals & our senior engineers. Basic: July 18–20. Includes overview on PV modules, controllers, batteries, inverters, & system sizing. Solar Water Pumping: Sept. 19–21. Taught by a solar water delivery professional with 15 years experience, includes overview systems & products with hands-on training. Contact Kyocera Solar, Inc. Training Dept • 800-544-6466 ext. 7148 Fax: 480-443-4562 seminars@kyocerasolar.com www.kyocerasolar.com

Tax credits for solar in AZ. A technician certified by the AZ Department of Commerce must be on the job site. ARI SEIA, 602-258-3422

**CALIFORNIA**
Campus Center for Appropriate Technology, Humboldt State University, Arcata. Ongoing workshops & presentations on alternative, renewable, & sustainable living. CCAT, HSU, Arcata, CA 95521 • 707-826-3551 ccat@axe.humboldt.edu www.humboldt.edu/~ccat

Energy Efficiency Building Standards for CA. Download or hard copy. CA Energy Commission, 800-772-3300 www.energy.ca.gov/title24

Efficiency & Sustainability, ACEEE summer study, Asilomar, CA. Building technologies for professionals. Contact ACEEE, PO Box 7588, Newark, DE 19714 • 302-292-3966 Fax: 302-292-3965 • rlunetta@erols.com

Workshops through Oct., RE, strawbale, ecological design, and sustainable living. Real Goods, Hopland, CA. Institute for Solar Living, PO Box 836, Hopland, CA 95449 707-744-2017 • isl@rgisl.org www.solarliving.org

Aug. 26–27: SolFest 2000. Fifth Annual SolFest by Institute for Solar Living, Real Goods, Hopland, CA. Speakers,

entertainment, over 40 educational workshops, exhibitors, tours, children's activities, & more. PO Box 836, Hopland, CA 95449 • 707-744-2017 • isl@rgisl.org www.solarliving.org

**COLORADO**

Sept. 2–4, '00: Crestone Energy Fair, 11th Annual, Crestone, CO, in the park. EV rally, RE workshops, solar stage, & RE tours. Contact Box 222, Crestone, CO 81131 719-256-4838

July 3–7, '00: Youth Renewable Energy Camp, Carbondale, CO. For indigenous & low income youth, on the wonders of solar, wind, & water power, during SEI's annual 4th of July Solar Potluck & Exhibition, & SEI Alumni Reunion. Become a mentor & youth camp supporter! Or just join us for some good fun! Contact: SEI, PO Box 715, Carbondale, CO 81623 • 970-963-8855 Fax: 970-963-8866 • sei@solarenergy.org www.solarenergy.org

Solar Energy International, hands-on workshops. 1 & 2 week sessions: PV Design & Installation, Advanced PV, Wind Power, Microhydro, Solar Cooking, Environmental Building Technologies, Solar Home Design, & Straw Bale Construction. Experienced instructors & industry reps. For owner-builders, industry technicians, business owners, career seekers, & international development workers. $500/week. SEI, PO Box 715, Carbondale, CO 81623 970-963-8855 • Fax: 970-963-8866 sei@solarenergy.org • www.solarenergy.org

Aug. 5-6, '00: Successful Solar Businesses, Carbondale. Richard & Karen Perez show how to make your RE business succeed by drawing upon their vast business experience. Cost $200, advance registration required, limited space. Contact: SEI, PO Box 715, Carbondale, CO 81623 970-963-8855 • Fax: 970-963-8866 sei@solarenergy.org • www.solarenergy.org

**IOWA**

Aug. 5, '00: 9th Iowa Renewable Energy Expo, Wartburg College, Waverly, IA. Tours of Waverly Light & Power wind, hydro, & fossil fuel facilities. Vendor displays, Electrathon car demo, workshops on active & passive solar, PV, wind. Hands-on classes wiring & raising a wind generator tower & PV systems. Contact: IRENEW, PO Box 355, Muscatine, IA 52761 • 319-288-2552 irenew@irenew.org

IRENEW PV Solar Traveler Trailer visits: June 3–4 Linn County Environmental Fair; June 16–21 MREA, Wisconsin; Aug. 5 IRENEW Energy Expo, Wartburg College, Waverly, Iowa; mid Aug. for 12 days powering sound stage at the Iowa State Fair, Des Moines, Iowa. Contact: IRENEW, PO Box 355, Muscatine, IA 52761 319-288-2552 • irenew@irenew.org

Iowa Renewable Energy Association (IREA) meets 2nd Sat every month at 9 AM, Prariewoods, Cedar Rapids. All welcome. Call for schedule changes. I-Renew, PO Box 466, North Liberty, IA 52317 319-875-8772 • irenew@irenew.org www.irenew.org

**KENTUCKY**

Appalachia-Science in the Public Interest. Projects & demos in gardening, solar, sustainable forestry, & more. ASPI, 50 Lair St., Mt Vernon, KY 40456 • 606-256-0077 aspi@kih.net • www.kih.net/aspi

**MASSACHUSETTS**

Greenfield Energy Park needs help preserving Greenfield's historic past, using today's energy & ideas, creating a sustainable future. Greenfield Energy Park, NESEA, 50 Miles St., Greenfield, MA 01301 413-774-6051 • Fax: 413-774-6053

**MICHIGAN**

August 4–6, '00. Sixth Annual Renewable Energy Fair, Lansing, by Great Lakes Renewable Energy Assoc. Keynote by Peter Dreyfuss, head of the Million Solar Roofs Program. Renewable industry & teacher education seminars on Friday, AE & sustainable development workshops, displays, demonstrations, & children's area. Free. Info: 616-887-0233 • glrea@aol.com http://ermisweb.cis.state.mi.us/GLREA/

Tillers International, classes in draft animal power, small farming, blacksmithing, & woodworking. 5239 S 24th St., Kalamazoo, MI 49002 • 616-344-3233 Fax: 616-344-3238 • TillersOx@aol.com www.wmich.edu/tillers

**MONTANA**

Sage Mountain Center, seminars & workshops, one day, inexpensive sustainable home building, straw bale const., log furniture, cordwood const., solar electricity, more. SMC, 79 Sage Mountain Trail, Whitehall, MT 59759 Phone/Fax: 406-494-9875 cborton@sagemountain.org

**NEVADA**

July 23–28, '00, GlobeEx 2000, Riviera Hotel Conference Center in Las Vegas. Includes the Intersociety Energy Conversion Engineering Conference and the NAPM/NPI Purchasing Green Energy Workshop for State & Local Government. Info: GlobeEx 2000, 2330 Paseo Del Prado #C101, Las Vegas, NV 89102 • 702-317-0777 Fax: 702-257-7999 • sulrich@ntsdev.com

**NEW MEXICO**

Profit From The Sun workshops, Moriarty, NM. RE, energy conservation, sustainable living, & energy independence. PFS, 505-281-1300 days • 505-832-1575 eves & weekends • proffit@flash.net www.proffitfromthesun.com

**NEW YORK**

Oct 15–19, '00. Bioenergy 2000: Moving Technology into the Marketplace, the 9th biennial Bioenergy Conference: NRBF 202-624-8464 • nrbp@sso.org

**NORTH CAROLINA**

How To Get Your Solar-Powered Home: Seminars 1st Sat. each month. Solar Village Institute, PO Box 14, Saxapahaw, NC 27340 336-376-9530 • Fax: 336-376-1809 solarvil@netpath.net

**OHIO**

RE classes, 2nd Sat. each month, 10 AM to 2 PM. Tech info, system design, NEC compliance, efficient appliances. In advance: $70, $90 w/spouse. Also hands-on straw bale post & beam building. Solar Creations, 2189 SR 511 S., Perrysville, OH 44864 419-368-4252 • www.bright.net/~solarcre

**OREGON**

July 25–28, '00: Grid Intertie System Installation, a pre-SolWest fair workshop in John Day, OR, by Richard Perez and Joe Schwartz. Classroom sessions and hands-on system installation on the fairgrounds. Tuition $275. EORenew, PO Box 485, Canyon City, OR 97820 • 541-575-3633 solwest@highdesertnet.com www.eoni.com/~solwest

July 29–30, '00: SolWest Renewable Energy Fair, Grant County Fairgrounds, John Day, OR. Over 50 vendors, 30 free workshops, & a silent auction including a 10 KW Jacobs wind generator, complete with tower & intertie inverter. EORenew, PO Box 485, Canyon City, OR 97820 • 541-575-3633 solwest@highdesertnet.com www.eoni.com/~solwest

July 31, '00: Utility-Interconnected Wind Generation for Home & Ranch, a post-SolWest Fair workshop in John Day, OR, by Joseph Singleton of Palouse Wind & Water. A one-day workshop on assessing & utilizing your site's wind potential. Tuition $45. EORenew, PO Box 485, Canyon City, OR 97820 • 541-575-3633 solwest@highdesertnet.com www.eoni.com/~solwest

Aprovecho Research Center, non-profit edu. org., two 10 week internships. Summer, Fall. Appropriate tech, sustainable forestry & organic gardening. Aprovecho Research Center, 80574 Hazelton Rd., Cottage Grove, OR 97424 • 541-942-8198 • apro@efn.org www.efn.org/~apro

**PENNSYLVANIA**

Aug 21–23, '00. Energy 2000 Energy Efficiency Workshop and Exposition: Pittsburgh, PA. Energy managers conference. By the DOE's FEMA Program, Dept. of Defense, & the General Services Admin. Contact: Florida Solar Energy Center, 1679 Clearlake Rd., Cocoa, FL 32922 800-395-8574 • joann@fsec.ucf.edu

**TENNESSEE**
Kids To The Country; a nature study program for at-risk urban Tennessee children. Sponsorships & volunteers welcome. Contact: 51 The Farm, Summertown, TN 38483 • 931-964-4391 • Fax: 931-964-4394 ktcfarm@usit.net

**TEXAS**
Sep 29–Oct 1, ‘00: Renewable Energy Roundup, Fredericksburg. RE exhibits, demonstrations, workshops, tours. TX RE Industries Assoc. & Texas Solar Energy Society, 512-345-5446 • R1346@aol.com www.renewableenergyroundup.com

The Houston Renewable Energy Group hosts regular meetings on the last Sunday of odd-numbered months at the TSU Engineering Building at 2 PM. HREG, PO Box 580469, Houston, TX 77258 hreg@egroups.com • jferrill@ev1.net mike.ewert@att.net www.egroups.com/group/hreg/info.html www.txses.org/hreg/HREGhome.htm

The El Paso Solar Energy Association bilingual Web page. Info in Spanish on energy & energy saving. www.epsea.org

**WASHINGTON STATE**
October, 2000: Solar Energy International workshops in the San Juan Islands. Microhydro Power, Oct. 13–15 ($250); Photovoltaic Design & Installation, Oct. 16–21 ($500); Wind Power with Mick Sagrillo, Oct. 23–28 ($500); Renewable Energy for the Northwest, Oct 29 ($75). Contact: SEI, PO Box 715, Carbondale, CO 81623 970-963-8855 • Fax: 970-963-8866 sei@solarenergy.org • www.solarenergy.org Local contact: ian.woofenden@homepower.com

**WISCONSIN**
Midwest Renewable Energy Association (MREA) Workshops. See ad. Call for cost, locations, instructors, & further workshop descriptions. MREA membership & participation: all welcome. Significant others half price. MREA, PO Box 249, Amherst, WI 54406 • 715-824-5166 • Fax: 715-824-5399 mreainfo@wi-net.com

June 16–21, ’00: ASES, Solar2000—Solar Powers Life, Share the Energy conference. June 16–18, ‘00: Midwest Renewable Energy Fair. Both events together in Madison, WI. See MREF/ASES ad.

June 12–16, ’00: Women’sPhotovoltaic Design workshop, Madison, $450. Learn system sizing, site analysis, hardware specification, & component selection. Supportive women’s environment. Co-sponsored by MREA. Contact: SEI, PO Box 715, Carbondale, CO 81623 • 970-963-8855 Fax: 970-963-8866 • sei@solarenergy.org www.solarenergy.org

# the Wizard speaks... More Reflections

**Physics**
Physics uses mathematics as a tool. Mathematics provides an efficient description of the physicist's model of reality. If the model is well-constructed, the mathematics will provide correct predictions for physical systems. The model need not provide a one-to-one correspondence with reality. It need not say anything about causality. The model needs only to give correct predictions about physical phenomena. It only needs to work.

**Vacuum Resistance**
If the vacuum energy field exists, it probably exerts a type of drag force on matter. This drag force could be manifested in several ways. The first is the phenomenon of inertia. The second might be the relativistic effects related to velocity. Finally, this drag force could be responsible for all or part of perceived red shifts.

**Technology**
Technology is the practical use of the results of science. It is most responsible for the state of our present day civilization. Whereas science is mostly neutral, technology can be either positive or negative in its effects. The best use of technology is to improve the quality of life, not to increase the quantity of things.

# Writing for Home Power Magazine

Home Power is a user's technical journal. We specialize in hands-on, practical information about small-scale renewable energy systems. We try to present technical material in an easy to understand and easy to use format. Here are some guidelines for getting your RE experiences printed in *Home Power.*

**Informational Content**
Please include all the details! Be specific! We are more interested in specific information than in general information. Write from your direct experience—*Home Power* is hands-on! Articles must be detailed enough so that our readers can actually use the information.

**Article Style and Length**
*Home Power* articles can be between 350 and 5,000 words. Length depends on what you have to say. Say it in as few words as possible. We prefer simple declarative sentences which are short (less than fifteen words) and to the point. We like the generous use of subheadings to organize the information. We highly recommend writing from within an outline. Check out articles printed in *Home Power.* After you've studied a few, you will get the feeling of our style. System articles must contain a schematic drawing showing all wiring, a load table, and a cost table. Please send a double spaced, typewritten, or printed copy if possible. If not, please print.

**Written Release**
If you are writing about someone else's system or project, we require a written release from the owner or other principal before we can consider printing the article. This will help us respect the privacy rights of individuals.

**Editing**
We reserve the right to edit all articles for accuracy, length, content, and basic English. We will try to do the minimum editing possible. You can help by keeping your sentences short and simple. We get over three times more articles submitted than we can print. The most useful, specific, and organized get published first.

**Photographs**
We can work from any photographic print, slide, or negative. We prefer 4 by 6 inch color prints with no fingerprints or scratches. Do not write on the back of your photographs. Please provide a caption and photo credit for each photo.

**Line Art**
We can work from your camera-ready art, scan your art into our computers, or redraw your art in our computer. We often redraw art from the author's rough sketches. If you wish to submit a computer file of a schematic or other line art, please call or email us first.

**Got a Computer?**
Send us the text for your article on 3.5 inch computer floppy diskette, either Mac or IBM format. We can also read ZIP disks (either Mac or IBM), Magneto-Optical disks (128 MB, 230 MB, 1.2 GB, and 1.3 GB, all Mac only), and CD-ROMs. This saves time and reduces typos. Please also send a hard copy printout of your article. Save all word processor files in "TEXT" or "ASCII TEXT" format. This means removing all word processor formatting and graphics. Use your "Save As Text" option from within your word processor. Please don't just rename the file as "text" because it will still include unreadable (at least to us) word processor formatting.

You can send your article via Internet to richard.perez@homepower.com as an attached ASCII TEXT file. If you are sending graphics, or articles with embedded graphics, then use this email address: ben.root@homepower.com

It is wise to telephone or email ahead of electronic file submission. This is particularly true concerning graphics files. There are many, many, many ducks and they all need to be in a row....

Got any questions? Give us a call Monday through Friday from 9–5 Pacific Time and ask. This saves everyone's time.

**Access**
Richard Perez, *Home Power,* PO Box 520, Ashland, OR 97520 USA • 530-475-3179
Fax: 530-475-0836 (24 hours a day)
richard.perez@homepower.com
www.homepower.com


**Mea Culpa**

Dear Mr. Perez, My husband and I live in a country town in Maine. Not too many people here use renewable energy, but it is on the increase. I'm sure you know how expensive these solar and windpower systems are. My husband is disabled. I work, and we have two children, so money is carefully spent in my home.

We bought and installed our system last spring, and prior to purchasing it we subscribed to *Home Power* and read every article in each magazine. When the subscription ran out, we began to purchase it at the local store because my husband didn't want to wait for delivery. We started our system with eight L-16 deep-cycle batteries, and it wasn't long before we realized that it wasn't enough.

We purchased eight more batteries last month and that's where the problem began. We asked the company to send us a wiring diagram. We received a diagram for a 24 V system in four rows of four batteries. Ours is set up in two rows of eight. My husband, being anxious to hook them up, could not figure out how to wire our batteries by looking at this diagram. He mentioned it to my seventeen year old son, who is quite technical and said, "Dad, that's easy. Do it like this."

As my son was drawing a diagram for my husband, my husband pulled out your Oct/Nov magazine and found the diagram on page 10 (check it out please). He then looked at my son's diagram and said, "Ryan, your diagram doesn't look anything like this one in the magazine." And my son told him that the diagram in the magazine was wrong, a typo. Not believing that your magazine would print a mistake, and not thinking my son would know more than your magazine, my husband proceeded to wire the batteries as they are on page 10.

Needless to say, Mr. Perez, my son was right and your diagram is wrong; the boards in our inverter blew due to reverse polarity. It also blew a little Trace meter that reads voltage, battery life, etc. My point is, please check that article. The cost to repair this equipment is setting us back by three months, and if your people don't catch mistakes like this, you're going to have a lot of people very upset with your magazine.

I wish you would email me back an explanation and offer to pay the damage to us, though as big companies go, I'm sure you won't do that. We'll probably still buy your magazine, but you'd better believe we'll think long and hard, check and double check other resources before we venture into any other projects that could be costly. Thank you for letting me bend your ear. I felt I needed to write to someone important who knew a lot about renewable energy. Sue Whitehouse

*Hello Sue, You are correct. The system block diagram in* HP73, *page 10 shows a battery wired for 48 volts, not 24 volts. This is an error, and it did make it past all our proofing processes. I have sent your email message to all of our editors and proofreaders as an incentive to be more careful in the future. I also missed this mistake. I will make no excuses to you because there really aren't any.*

*It is always a good idea to double check the math and wiring hook-ups when venturing into unknown territory. Even if you know what you are doing, it's a good idea to use a volt meter to verify battery pack (or PV array) voltage before hooking it up to sensitive equipment.*

*I am dreadfully sorry that you used this diagram to rewire your system and that it resulted in damage. While we strive for clarity and accuracy, we can assume no responsibility or liability for the use of our information. While you may think that we are a "big company," we are really just a collection of RE users like you. I can understand how dreadful this is for you. My apologies. Richard Perez*

**Iowa High School Electrathon Team**

Dear *Home Power* crew, Since last August, I have been helping the Muscatine High School Electrathon Team. These students are building an electric race car from the ground up in less than six months. For many of them, this will be a quantum leap from the computer to using a wrench.

To help these forward-thinking young people, I have been sharing all the wonderful *HP* EV and battery articles. This has motivated me to start reading *HP* starting at volume 1—what an awesome experience! I have over twenty years in this field, and I am constantly finding things I had forgotten or overlooked. *HP* is definitely not a "read once" endeavor.

I have been searching the Web for information at the same time. *HP's* information beats the Web hands down, every time. It has been absolutely amazing how just as the students get to a point that they need more information, *HP* comes out with an article on that exact subject. I only hope all the other Electrathon teams have access to your magazine. Hmmm, on second thought, maybe not! We would like to win, and *HP* is making that possible…

If you would like to view the Muscatine High School Electrathon Team's Web site, which was developed by team member Dan Gruemmer, go to http://cpeconline.com/ecar. You will find links to other Iowa Electrathon team Web pages there. I know you will be impressed by the impact we are all having on the next generation. Environmentally yours, John R. Root, Muscatine, Iowa

**Microhydro and Fish**

Dear *HP*, First off, I'm an ardent fan of your magazine. I know *Home Power* is driven by a desire to do the right thing environmentally, so I hope that my comments aren't taken in a negative way. *HP76* carried a couple of excellent microhydro stories. That's what concerns me.

Recently, a series of Endangered Species Act listings has forced everyone in the Pacific Northwest region to begin dealing with failing salmon runs. We can no longer pretend that there isn't a problem. Those of you living outside the region may not appreciate the magnitude of the situation. These listings are the first to directly affect large metropolitan regions, such as Seattle. Salmon recovery is a very, very big deal up here.

There's a photo on page 64 of *HP76* showing a small dam that was constructed to provide an intake. I don't know anything about this site. Perhaps it can be proven that there are no fish in this waterway. Perhaps there are larger barriers downstream, or that culvert just upstream was perched, cutting off passage. All I can say for sure is that this intake structure is big enough to impede fish passage. If there are listed fish in this waterway, the act of constructing any such impediment constitutes a "take." What's a "take"? Basically, it's anything that harms a listed species in any way, and it's illegal under the ESA. Aside from the physical barrier, there's another issue. Perhaps a more knowledgeable reader could comment on this, but I'm pretty sure that the diversion of water from the streambed without a water right could qualify as a take no matter how it was accomplished.

As I said, perhaps in this situation no fish will be affected. But how many other microhydro structures already exist or will be built in critical salmonid habitat? People trying to do the right thing may very well be hurting salmon runs and breaking the law in doing so. Bill & Patti Barmettler, Chehalis, Washington bpbar@juno.com

*Dear Bill & Patti, We all share concerns over the effects of dams. While your specific concern is for salmonid-breeding watercourses, the truth is that there are many species, both fauna and flora, that can be affected by water diversion of any kind. Fortunately, it's less of a problem than you think. Most (but not all) microhydro systems go in on small creeks that have no resident fish population. Even so, a user or system designer must be careful to leave enough water in the stream course for frogs, bugs, trees, etc.*

*Since most of these systems dump the water right back into the stream after spinning the runner, the main concern is providing adequate bypass water along the length of the pipeline. With a year-round hydro, the crucial times are summer and fall, since water flows are usually less then. During winter and spring, there is almost never a problem in fishless creeks—lots of water for everybody.*

*A creek with a year-round fish population is a different story. Intakes need to be constructed with adequate screening and bypass for fish. I can't think of a state without laws governing this. Your state of Washington has* very *stringent requirements. So much so that I've had many customers in Washington just give up on the whole idea of even a very small diversion in a fish-bearing creek. Your DNR does* not *encourage diversions of any kind in a waterway with* any *fish in it, salmonid or not.*

*While your worst fears are valid concerns, they do seem to somewhat exceed your knowledge of either good microhydro design or the water needs of salmon. I haven't seen the creek on page 64 of* HP76, *but judging by the water level and the water stain in that culvert, I'm pretty sure that no salmon is going to try to spawn in that small a waterway. Any that did would be quickly picked off by predators. Also, salmon can jump incredible natural obstacles. The tiny little dam in this system would present no difficulty, all other things considered. Bob-O Schultze, Electron Connection econnect@snowcrest.net*

*Hi Patti & Bill, I too, share your concerns. Damming a creek or river is a big deal. Fortunately, not many home-scale microhydro systems use dams, nor do many suck fish-bearing creeks dry.* Home Power *magazine will begin asking for fish and fish habitat mitigation info from every microhydro system article we print. But we have decided that the problem is not big enough with home-scale microhydro systems to demand it as a requirement for publication. Like the potential for wind genny bird strikes, we leave it up to the conscience of the system owner to do the right thing. Michael Welch*

*Hi Patti & Bill, I coordinated the workshop in question, and want to respond to your good letter. We definitely asked the fish question before we got involved in this installation. The owner assured us that there are no fish in this stream. And even if he was not correct in this, the dam he designed and we built created no more drop than the culvert already had. On top of that, immediately above the culvert, there are three overshot wheels that would certainly stop fish.*

*That said, I think we could have done better with the design. We were also assured that the stream did not have much silt, but in my last visit to the site, I saw that one side of the dammed area was full of sand and rock. I think a better intake structure at this site could have been built with a screened box directly under the culvert, instead of using a dam.*

*Michrohydro is a small niche market, and each stream and system is different, so we are often pioneering when we do a system. I would love to have someone with a lot of experience write us an article on microhydro intakes. There are ways to take a small percentage of a stream's water without disturbing the bulk of the natural flow, and without impeding fish. Your letter is a good reminder to consider all the effects of our RE systems, and I thank you for it. Ian Woofenden*

**One Dam On Its Way**

Please give us some guidance. We are going to install a hydroelectric system at our homestead in the SW Virginia mountains. We have a flow range of 115 to 200+ cfm. We will build a six foot high dam with floodwaters flowing over a rock-covered portion of an adjacent field that slopes toward the creek. The opposite bank faces a granite rock cliff. Since the pressure pipe run only needs to be about 40 feet long to avoid all floodwaters, we plan to use all the flow and build a small fish race for our minnow-sized trout. Thus, I believe we could use two fixed-blade propeller turbines, one at 70 percent flow and one at 30 percent flow.

Being a retired construction management mechanical engineer, I'm confident about doing the site work. What I need from you is a list of propeller and crossflow turbine manufacturers and suppliers of batteries, inverters, generators, and electronic governors. Please also recommend some in-depth books on the subject. Chester Kalinoski, Roanoke, Virginia

*Hello Chester. What a timely letter, considering the previous one. We don't have lists for the type of turbines you are looking for, but for the balance-of-system equipment you can contact many of our advertisers. Many of them are quite knowledgeable about microhydro, and can probably help you there as well. Also, check the* Home Power *InBiz online database on our Web site, with a search for hydro.*

*While it sounds like you plan to mitigate the fish problem, I strongly suggest you consult a local fish biologist and a stream bank restoration specialist. Maybe you have done so already, but the plans for taking the entire stream flow and letting flood releases flow over a field and the bank of the stream are fraught with danger. Decisions in these areas are often best left to those with lots of experience.*

*And, don't forget to take plenty of pictures to document your new system and its construction. Projects like this make great write-ups for* Home Power. *Michael Welch*

*Hello Chester, It sounds as though you have an interesting site with good potential, and your background lends itself to the work ahead. Your plans to construct a six foot high dam will require permission from the local fisheries folks and other state agencies. As long as you don't interconnect with the grid, the Federal Power Act of 1934 shouldn't apply. I don't think you need to notify the feds.*

*A few hints on dam design for microhydro: It often pays to include a "draw down gate" in the dam design. This lets you drain the pond and remove accumulated silt and gravel from behind the dam (with state draw down permits). It also helps with dam inspection and maintenance. I would also include the turbine intakes, control gates, and trash racks in the dam itself. You will probably place the intakes at the end of the dam opposite the cliff face, depending on bedrock. It is a good idea to position the intakes 90 degrees to the stream flow just upstream of the dam.*

*A floating timber can be placed across the front of the intakes to skim the surface and guide floating trash toward the spillway. Some folks use a notch in the top of the dam about 2 feet wide and 4 inches deep at the downstream end of the skimmer. This carries trash over the dam and also helps to insure some downstream flow below the dam.*

*When designing your turbine intakes at the dam, be certain to select the area of the rack below the surface to maintain a max velocity of 1/2 foot per second. Assume that the vertical bar rack will block about half of the area when you do the computations. Also plan to submerge your penstock's (pipeline) intakes at least 2 feet in order to avoid vortices. These could suck air into the system. I would recommend at least a 10 inch PVC penstock on each unit.*

*Regarding equipment: Your plan to use two units that split the flow 1/3 and 2/3 is good conventional practice on larger sites where it is important to optimize annual output. Depending on your expected loads, I would recommend a simpler approach. Two smaller units totaling about 70 percent of maximum flow should be sufficient. 115 cfm on 6 feet of head will develop around 600 watts of power with my 8 inch Francis turbine. This is enough power when combined with the correct battery bank and inverters to run a home quite comfortably. A second unit could be added to use winter and spring flows if more power is needed or if you plan to handle some minor heating loads. You may want to size the first unit smaller to match extremely low flows.*

*I would contact the local office of the USGS and do some research on potential flow at your site. Concentrate on the lowest flows in late summer and fall. Size your smaller unit to accommodate these numbers, and then go larger with the second unit. Always consider leaving some in-stream flow below the dam to support aquatic life. I'm sure that the state can help you with this. Your fish ladder designs will also have to be approved.*

*From what I read in your letter, I feel that your site is best suited to either a prop or Francis-type reaction turbine. Regarding possible turbine suppliers: Peter Ruyter (turbin@cargo-kraft.se) manufactures small prop turbines in Sweden. The company name is Cargo-Craft. You can contact him by email. I am going to introduce my small scroll case Francis units at the Midwest Renewable Energy Fair in Wisconsin this June. My "Neptune" design matches your site requirements well. Combined with the special brushless alternator I supply, and all-stainless construction, it should give many years of trouble-free service. Please feel free to contact me. Best Regards, Ron MacLeod, C. MacLeod & Co., 2131 Harmonyville Rd., Pottstown, PA 19465 • 610-469-1858 Fax: 610-469-1859 • microhydro@dplus.net.*

**Code Gestapo**

Richard, I would like to address all the supposedly technical people trying to restrict the natural advancement of the renewable energy industry in the USA. Also all those people at Sandia and other institutions and government-funded autocratic and bureaucratic agencies acting for the supposed good of us "little people." In a word—give me a break!

In a something like a mix of "The Emperor's New Clothes" and a sad version of "I'll do what's best for you even if you won't," it seems that everyone wants to control us. Now that RE is becoming big business, everyone wants to regulate, control, and manipulate it in every way possible. Where were these people back in 1990 when you could not even find one piece of equipment to UL label? Most of those systems, though upgraded, still operate very well without the blessing of the local black-booted government lackey.

Right now, a person can go anywhere, put a battery bank, some solar panels, and an inverter in their $100,000 motorhome and cruise the country, free from inspection and government intrusion. Put the same thing in your home, and in most areas, watch the code people come out of the woodwork.

Plus it suddenly costs about 50 percent more. If you are hooking up to the utility in any way (though I don't know why anyone would want to do so), it gets even uglier. If we think we will get a cleaner utility by connecting a few homes to a grid that serves so many varied interests, we are kidding ourselves. Public utilities, just like most government agencies, do not exist for our benefit, but for the benefit of the agency itself. If you don't think so, try to shut one down.

Yes, there are legitimate issues such as battery location, inverter disconnects, even grounding, but most of this is really

covered in nearly every way in the original *NEC* code book. I have a version from 1984, and from a common sense standpoint, it's all there. I think people should know that though personal residences and commercial property are covered by the *NEC,* utilities themselves are exempt from the code, along with all government properties, national parks, some municipal facilities, etc.

I am not attacking the individual code person or utility worker. These are good people, working every day and giving, in most cases, their best effort with malice toward none. However, the entities that employ them always tend to be autocratic and bureaucratic in the way they handle our interests.

The main elusive component left out is the ability to talk to someone on a common sense basis. Many times you get either doctrine and dogma or an "I'm smarter than you are" reaction. It seems to me that if RE manufacturers were left to their own devices, given a specific set of specifications to adhere to, and left to regulate and police their own industry based on feedback from the field, we would have a very viable and safe industry without all the needless red tape, contrary and contradictory rules, etc. It's my opinion that what we are doing as a grassroots movement means more than a bunch of rules, some bureaucrat's career, or the remote possibility of some badly installed systems.

Here are but a few examples of how real-world facts collide with code-based thinking:

Fact: Nearly all diesel truck systems are 24 VDC start, so they have batteries that operate at 12 VDC and 24 VDC. Trucks then have multiple alternators or circuits that charge batteries, sometimes rated in hundreds of amps. Why are these systems not considered dangerous? No one has ever been electrocuted by a truck starting system, even though it is not grounded. Yet in a home with a small 12 or 24 VDC PV system, the resulting voltage from the 24 VDC array is considered lethal by some. Rule #1 in life: If it doesn't meet the common sense test, it is probably bunk!

Fact: All the concern over grid-tied inverters centers on one pivotal point—that islanding will cause severe problems and potentially kill utility workers. I worked for a municipal utility in 1987 and 1988, and as part of my job, I was required to attend lineman schools in case I was needed to fill in during an emergency, which I did several times. What you learn about working with high voltage after two intense week-long schools is this:

1) Never assume any line is dead.
2) Never assume your buddy checked it and it's dead.
3) Disconnect all possible power feed sources before working.

So, unless something has radically changed, why the hubbub over this? Anyway, a single or even multiple inverter set could never stay on line in sell-back mode past a couple of cycles or 1/60th of a second. For one thing, the load would be so enormous that the inverters would trip off line on overcurrent. Second, if other inverters were connected to the same line, all would be fried as soon as one inverter stack, unsynchronized without the utility signal, began to feed another inverter. Without the utility frequency and phase angle reference, they would all be different. Try it yourself if you have some time and about $6,000 to waste. It would be like closing unparalleled AC generators onto a single line source or feeding the output of one inverter to another. Without the grid, nothing can go anywhere.

Fact: Common sense says that what works well in one case should work well in another. Take welding cable for battery connections. Ever try to use building cable to connect your batteries? In an effort to keep with the code, I did. What a pain. Ever wonder why welding cable is what it is? Most arc welders are DC and range from 50 to 200 volts and can be 25 to several hundred amps.

Welding cable is also used in locomotives, which by the way are also mainly DC-powered, motor-driven units where the smoke comes only from the onboard diesel generator. These cables are made flexible for one main reason according to ASTM and IEEE standards. DC induces voltage and creates a magnetic effect. When large currents are passed thru DC cables, they must be able to flex. Indeed, they do move with the current flow. Test it yourself. The same must apply to the DC sources feeding batteries.

Regardless of the code, sunlight is not the prevalent factor in determining what cable should be used to connect modules; flexibility should have priority. Common sense should determine what battery cables and PV cables are used, not code. Why can't the rest of the rules used in electrical installations be more common-sense based? Though electricity is somewhat complex in nature, the basic rules for its use are really very simple.

For many of us, the RE power system becomes an almost organic part of our homes and our lives. People build their own homes every day, in many different parts of the country, under widely varied rules and codes, and with different ideals and goals. Why should some person tell them how to live, how to think, etc.?

This to me is at the heart of the dispute—free thinking as opposed to regimentation and restriction. It is probably too late to stop these people. They have an agenda to supposedly mainstream RE and apparently this means adopting the same old worn out tactics of regulation and intimidation. My only hope is that the majority of people considering the alternative energy lifestyle do so in a way that limits the effect and interaction of the establishment. It really is an us vs. them issue, after all. Bill von Brethorst brethors@3rivers.net

*Hi Bill, and thanks for your letter on this contentious topic. Here's my view: There are two ways for people to operate with each other—cooperatively and coercively. Codes, rules, and regulations are all in the coercive category—in the end they have guns behind them to force you.*

*I believe in a cooperative society. We should only bring out the guns as a last resort. But many people are not willing to trust their fellow human beings, and others will not take responsibility for their actions. So most social systems these days are pretty far along the continuum from cooperation to totalitarian control.*

*I think we are much farther along that continuum than we need to be. I have nothing against standards. I can choose to use FedEx to ship overnight packages (for instance) because I respect the standards they hold up. But when we have a single standard imposed from the top, it's way too easy to end up with a huge bureaucracy and a lot of nonsense. It also stifles innovation, and technological and social improvement. If all codes relating to RE today were fully enforced on the pioneers of this movement 20+ years ago (or even now…), we wouldn't have much of a movement.*

*To me, renewable energy is common sense and liberating. You don't have to be a tree hugger or an electronics nerd to see that the sun shines, the wind blows, and the water flows, and it just makes sense to capture that energy. This technology frees people to make choices about their own energy generation and use. I find the whole code system to be very antithetical to the essence of RE. The politics surrounding it also makes me ill. I'm glad you and others are actively fighting for more common sense. Ian Woofenden*

**Doesn't Hate Utilities, But…**

I appreciated the story of *HP's* start. Wow! You guys really did what the rest of us said we would do before we sold out and became the "establishment." Won't mention any names (me!)… Now, we are planning and saving to do the RE country homestead in comfort as retirees (how tough is that?!).

I think the article mix is fine; don't change a thing. I love guerrilla solar! My brother is a utility engineer and nuke proponent, and I mail these to him. I don't hate the utilities—they brought us this far. Now they need to change, and only the marketplace (us) can make it happen. Deregulation is the first step even if it means interim bullshit like selling pollution rights, etc. I still drive a car, so I live in a glass house. Gordon Trump, gtrump3@redrose.net

**RE Conflict of Interest?**

For the past five years I've been doing one small project a year. I'm finding that any technical support that may be offered is laced with conflict of interest. This conflict comes from engineers (?) who make their living by selling you lots of equipment, and are not inclined to deal with shoestring homeowners like me. We ask too many questions, take up too much time, and buy too little.

I am on grid, and will continue to stay on. I am finding that I can greatly reduce my monthly bills as long as I do *not* intertie with the grid. I have a 30-tube Thermomax hot water heating system, two solar panels mounted with a Wattsun tracker, two sets of wheelchair batteries, a 600 watt Exeltech inverter, a wood-pellet fireplace, and radiant floor heating. I hope to obtain an Air 403 (industrial 3-wired) wind generator within the next few months.

I am currently paying about $25 dollars a month from spring through fall to run my home. The city has come to my door three times in the last four years, because the utility company has notified them of the continuing drops in consumption.

I went completely off of natural gas about five years ago (I live in a city in a gas-producing province). You should have been here for the fun. There was shutting off of meters, cutting of pipes, refusal to disconnect, threats of property destruction to get their underground pipes back, and ultimately vandalism (by them). I've learned that it is sometimes better not to ask permission, but to say "oops" for what is now done. It works!

I'd like to thank you for publishing *Home Power* magazine. I couldn't have done it without you. Name withheld to protect the innocent, Alberta, Canada

*Hello friend. What a great story! You are in the trenches doing it, and enjoying it in spite of the utility's interference. More power to you.*

*It sounds like you've had some bad experience with people trying to sell you RE equipment. It is time for you to change dealers. Not all of them have just the sell in mind. Many dealers got into the field because they felt it was the right thing to do, and those are the ones who are usually willing to go out of their way to help, not just sell. Search around, and be sure to ask the question, "What can you do to help me with my projects?" Once you get the answer you are looking for, give that dealer your business. Michael Welch*

**Homebrew Parts Availability**

Thanks for your invitation to write to you and ask for what I need. I read your articles for the small systems and their application. I can neither afford nor many times justify large expensive systems. Our small daily sunlight here on the East Coast allows me to use rudimentary, stand-alone systems that I can easily afford and maintain.

I love your homebrew articles, and actually wish you would include more than one article per issue on lower-priced systems. If I had a gripe it would be that these systems use electronic components that I simply can't find! I'm not an electronics expert, as so many of your readers seem to be. I wonder if it would be possible for you to evaluate the components as to their availability, and suggest replacement parts that may be easier to obtain before you print these homebrew articles!

Try spending more article time evaluating the smaller stuff, suggest questions that I may be too stupid to ask for myself, so if I purchase the next best thing, I'm not getting burned because I didn't know what I should be looking for. Thanks for a good wintertime read. Forrest C. Hanes, Auburn, New York

*Hello, Forrest. We are always looking for good homebrews to publish in* Home Power*. The truth is that great homebrews are quite rare. In homebrews that I originate, I try to keep to a Radio Shack parts set. This is not because Radio Shack has the best or the cheapest parts, and they certainly don't send us bucks for recommending them. I try to use Radio Shack parts because everyone out there has easy access to them. In some cases, the needed parts are too esoteric for Radio Shack to stock. If this is the case, I fall back on other suppliers, mainly Digi-Key, which has most everything imaginable. Heads-up, homebrewers! If your design uses parts made of unobtanium, then your design cannot be constructed by others. Keep it simple and keep it standard.*

*Just lately, RE has gone mainstream. So we have a plethora of larger, more expensive systems. This doesn't mean that everyone needs a $20K system to meet their needs, just that some folks do. One of the greatest beauties of RE is that you*

*don't have to buy any more than you really need. Readers, please keep sending us articles about smaller systems.* Home Power *is about home power. We don't care how much you spent on your system; if it works and meets your needs, then it is suitable for publication in these pages. Richard Perez*

**Big Isn't Better**
Dear *Home Power* people, I've been on board reading your magazine from its inception, and can't help but feel how important and influential it has been in encouraging the growth of independent renewable energy systems. *HP75* contains articles representative of philosophies espousing ideals at both ends of the spectrum—the best and worst on the consumptive scale.

I was particularly impressed with Melanie Chacon's "vision," indomitable spirit, and inspiring determination and capabilities—worthy of much praise! Also, the Surber/Corrigan "Small and Simple (Cabin) in the North Woods!" The "worst end" of the consumptive scale was eloquently epitomized by the "Barton Motor Coach." Gross! Gag me with a 200 amp fuse! Whatever happened to Schumacher's espousal of "Small Is Beautiful?" I find it disheartening to see the preponderance of articles suffering from "affluenza."

Aside from this critique, I find more positive articles and information to look forward to each new issue, for which please find enclosed remittance for my subscription renewal. Sincerely, Radken, Shelburne Point, Vermont

*Hi Radken, and thanks for your letter. We try to keep a balance between the low-budget systems and the mega-systems. While our hearts are with you and folks who can squeeze an amp-hour out of a turnip, we also want to see RE go mainstream. While some of the big systems seem wasteful and inappropriate, they do show what can be done. But we still do prefer to see systems of all sizes show concern with efficiency, not just volume.*

*Keep telling us what you want, but remember that we have a wide readership and we are trying to appeal to a wide variety of RE interests. I suspect that the readers who enjoy the large system articles could write us letters complaining about the funky hippie systems that we have been known to cover. The bottom line is that we can't please every reader with every article, which is why we publish a variety. We also urge you and others to submit articles on small, efficient RE systems. Ian Woofenden*

**Another Wind Genny In a Tree**
How's it going, *Home Power?* I just got my last issue. I could not believe the turbine in the tree. I thought I was the first. I put my Air 403 up in July, as you can see by my picture. I thought you would enjoy seeing it.

I told a few people at the Midwest Renewable Energy Fair and they all said, "How?" I strapped the 20 foot pole to the tree using cable scraps from the local utility company. I used a hatchet and topped the tree to prevent wind resistance. There is a building below it. Jason Busch, Land o' Lakes, Wisconsin

*Hi Jason, Well, our first wind generator tree tower has been in operation for 17 years now, and we were certainly not the first either. As a tree trimmer and a wind maniac, I find wind machines and trees to be a wonderful, if unconventional, marriage. Richard has urged me to write an article on the subject, and I will probably do that one of these days.*

*I do have some concerns from your letter, and it's these concerns that especially make me want to do a comprehensive article. I think tree towers are very much a fringe thing and not for the average (whatever that means) RE system owner. And I think when you go out on the edge, you have a responsibility to do it in a relatively sensible way. Please take my comments as constructive criticism, and as words of warning to others.*

*First of all, I find tree topping to be a questionable practice in most situations. While I'm not a fundamentalist about topping, I think many concerns of the anti-topping crowd are right on. I won't delve into it here, but I will say that though I topped our first tree-tower tree, the trees I've used and picked for our second and third tree towers will not need to be topped. I'm also concerned that you did the topping job with a hatchet. In order to be an effective and long-term tree tower, you want to keep the tree healthy and alive. I'd recommend that you go back up with a sharp saw and make a clean, sloping cut that*

*can drain and heal well. This cut should be just above a healthy branch or branches. Also, some species take topping much better than others. I hope you consulted with a local arborist before you picked your tree.*

*My second concern is in your description of attaching the mast to the tree. You say you "strapped" it on. Anything that goes all the way around a tree will tend to girdle and kill that portion of the tree. I recommend through-bolting your mast as the least damaging way to attach it to the tree.*

*My third concern is that I don't see any guy wires or ropes on your tree tower. Perhaps they don't show up in your photo. While you may well get away with this for a shorter or longer time with such a small machine, I think it's a questionable practice. Trees au natural,* without *masts and wind turbines in them, often blow over or lose their tops. You've added a lever and a resistance up there, and have your investment in the machine and installation to think about. There's also the issue of gyroscopic forces to consider, especially with larger machines. I recommend guying tree towers.*

*Well, as you can see, this is a subject that interests me. I'll cut this off now, but I hope we can jaw about it more at MREF in June. And to all you tree tower owners or heirs, I'd like to hear about your experiences, and see your photos. They just might show up in* HP *one of these days. Ian Woofenden, PO Box 1001, Anacortes, WA 98221 ian.woofenden@homepower.com*

**Component Sources**

Hi Folks, I noticed in *HP76* that someone is looking for a 115 V KWH meter. I got a used one a couple of years ago from Herbach and Rademan (800-848-8001; www.herbach.com). It was very reasonable (~$30.00 + box to fit for $10) and in very good condition, and I am using it now. Unfortunately, I don't see the 115 V KWH meters available in their current catalog. However they still do have a 3-wire 240 V model. It seems to me that this should work fine with the 115 V load connected to one leg and the neutral. Perhaps you folks at *HP* would like to get one and check it out to see if it would work OK. I have mine set up with a plug and outlet box so I can just plug it in and plug an appliance in to it so I can check out the cumulative energy used.

While I'm at it, I want to mention C&H Sales (800-325-9465; www.candhsales.com). They are a source of both heavy duty rheostats (potentiometers/variable resistors; 25/50 watts and up to 5 A), and *very* high power resistors for use with power diverters (some can handle up to 170 amps!). I got a couple of these for some friends. They are ribbon type, edge-wound elements on ceramic cores, and very impressive; 750 to 6,000 watts dissipation. You need to call them before ordering, since their selection varies. Jonny Klein, K7JK

*Thanks for the good ideas and leads, Jonny. I've done business with C&H Sales many times over the years. Good folks! Richard Perez*

**Democracy Rack**

Hullo Richard, Just a note to ask if there is to be a further report from the Democracy Rack. I am very interested, as many readers will be, in the ongoing performance of the various solar panels. I trust *Home Power* has not been pressured to discontinue the reports. I found out that the results from the Solfest Shootout in June '98 became hard to get and the gentleman who conducted the tests had his hand smacked!

On another note, I would suggest that a report on the solar power system for the Olympic Stadiums in Sydney might be of interest to readers although not exactly "home power," I admit.

I am looking seriously at a project to generate power from the controlled burning of automobile tyres. This has been done on a large scale, but we would look to test a small unit requiring about 300 tyres each day. This would address an ecological disaster and be a unit run by unskilled labour in the poorer areas. Anything along those lines that you may know of?

I am nearly finishing a project involving automatically retractable guyless wind masts. We have them working manually and will complete the automation in a few months. The client is sensitive about publicity, but the project will eventually be publicized.

I never got to find out if Trace inverters could be connected in a ring configuration for power sharing between separate battery banks. No one has been able to tell me—maybe no one has tried it? Richard, many thanks for your efforts with *Home Power.* Carl Emerson, Auckland, New Zealand

*Hello Carl, We are planning more testing of the PVs on the Democracy Rack, but we haven't gotten around to it yet. I suspect we'll do another round of testing this fall. We're stretched pretty thin this summer with energy fairs and new construction here at FMI, in addition to magazine production. We've had no negative responses from the PV industry about our testing, and I don't expect any. We ran our test procedure by every PV maker before we ever began testing.*

*The auto tire thing sounds interesting. Sorry, but I know nothing about this. Air pollution may be a problem.*

*I don't think that anyone has tried the "ring configuration" using Trace inverters. Sounds interesting. Please keep me posted on what you discover. Richard Perez*

*Richard's suspicions about the burning of tires is right on. This is not much different for the environment than burning fossil fuels. Significant scrubbing of the stack exhaust is required. Lots of airborne particulates are involved in this process. $CO_2$ is spewed into the environment, no matter how much scrubbing is done.*

*Citizens in California communities that have a tire burning plant nearby are very displeased with the air pollution from the plant's operation. Just this last winter, a lightning strike hit a pile of tires at the plant, causing a fire that was nearly impossible to put out, and burned huge amounts of tires—without the pollution mitigation that a plant has.*

*Burning tires is a bad idea. Auto tires are 100 percent recyclable. The only reason good recycling technologies have not been fully implemented is because the industry is balking. It is cheaper for them to manufacture new tires with new raw materials. Some communities have used old tires as road base, with mixed results. Michael Welch*

**Keep It Simple**

Dear *Home Power* crew, I read with interest the letter from Catherine Stanley in *HP76,* page 146. We too have what most consider to be a small and mainly DC system, which works fine and meets all of our needs. We greatly understand her interest and viewpoint. In fact we also often wonder why folks can't scale down and go "independent." Lazy? Unknowledgeable? Misinformed? Why, why, why?

Even our friends and family, who had seen our place "in action," seemed to think either that we were "exotic" or "eccentric." And they don't have any interest in going electrically independent themselves. While they marvel that our energy costs are only about $350/year (LPG), economics (too high payback costs) is the pat answer to the bulk of their objections. Also, they see an RE system as limiting their lifestyles. I have come to realize that there are other reasons that we who live on RE may not have insight into.

RE is mainly DIY. The bulk of folks who live this way are more rural in location (and attitude?) and their systems reflect an appreciation of "basics," hands-on, and bare bones economics. These are not people who accept perpetual payments as a given in life. Pay as you go is more their preference. Also being "on site" rather than working away from home allows options for interacting with daily chores rather than needing to seek help for chore relief.

Those who work away from home have different needs, which impact an electrical system more by requiring higher usage at less replenishable times. I can and do wash clothes during daylight hours and use a clothesline to dry them. Someone who works away from home may need to wash in the evening hours and use a (gas) dryer to get this job done quickly. Likewise with other chores—vacuuming, microwave to defrost, ironing clothes, etc.

So an RE system needs to be able to be as "powerful" and available as a utility for these folks to accept it. This means $$$, to say the least. And this doesn't even scratch the surface of the "status" or "convenience" issues. Sun Frosts don't have built-in ice makers or a water-on-door option, so keeping an energy hog sounds reasonable to those who accept these items as "normal" (we use ice so seldom it becomes stale!).

Add to this the DC vs AC issue, and again the options decrease. Sure you can find a 12 VDC blender, but the hefty price quickly outweighs the usefulness, and alternative options are used, or switching to AC becomes cost effective. We have had this issue hit home big time with us since we put our "solar" home up for sale. People just don't want to *think* about electricity. It seems that paying a bill is easier than thinking, and electricity basically scares people when they do have to think about it!

So we have had to look long and hard at our efficient little system. We have already doubled it—twelve 60 W panels and 1,400 AH batteries. Going all AC is the next effort for us. I will miss the non-hum of DC fluorescent ballasts, running my laptop with a *direct* connection, and the simplicity of the system needed to run the 12 VDC Sun Frost. I won't miss the inverter sounds (in the house), and needing to remember which circuit is DC and which AC, or the keeping track of how many items are in use at a particular time (gentle on system/amperage limits). Besides, we have earned the privilege of a few comforts, and taking it a bit easier on our "aging" selves too. Bill kids that we could burn 55 gallon drums of crude in our yard and still be "greener" overall than the "greens" of the city!

Bottom line? Do what is best for you and your situation. Leading by example is as honorable a statement as one can manage. Congrats on a beautiful lifestyle, Catherine, one that others may never know because they won't give it to themselves. Katcha Sanderson • sandkats@excite.com (see the Sandersons' system article in *HP61.)*

**The sun is the emissary of the Great Spirit, without which all life on Earth would perish.**

These are words of wisdom from a good friend by the name of Bob Larson. He was the owner of Sunlight Works out of Sedona, Arizona. Bob has left us. He passed away on Tuesday April 11th at his home in the sun.

Bob was a solar pioneer. His love of the sun and the power that it gives us was an inspiration to all who knew him. His radiant smile broadcast happiness and love. It sent out the message that he loved what he was doing.

With his wife Heather, he championed solar energy in the schools of Arizona, and in Africa and Latin America as well. He was a teacher, a mentor, a provider to his family—a good man. We will miss his presence, and especially that smile.

Bob's work was mostly in the passive technologies of solar—hot water, solar cooking, and passive solar design. This is appropriate to his own passive style. The bottom line for him was sharing, not the dollar sign. Smile on, Bob.

Your friends from SEI, Sunsense, Arizona Energy Office, and all the recipients of that smile.

Photo courtesy of *Valley Journal* and Carol Craven

Richard Perez 

# Check Your PVs Before Their Warranty Expires

We recently installed a 24 volt system here at Funky Mountain Institute. While doing this, we rewired many of our older 12 volt modules to function in the new 24 volt system. See the article on page 30 of this issue for the details. While rewiring the PVs, it struck me that this was an excellent time to test each module.

After all, the modules were not wired to any array, and about to be rewired into a new array. At first, Joe Schwartz groaned—I was making more work for him to do, and we would probably gain nothing from his extra work. As it turned out, Joe was wrong—we did find problems.

We discovered three modules (out of twenty tested) that were not putting out any power at all. One of these modules was nine years old and the other two were almost ten years old. We bought these modules back in the days when ten years was a standard warranty period for a PV module. If we had not tested these PVs, we might not have discovered their failure before their warranty period expired.

We assume that these PVs died because a series cell connection failed. The culprit is probably thermal cycling. Daily expansion and contraction can cause a series intercell connection to fatigue and break. We actually have no real proof of this; it's just our best guess. Somewhere in the current path from cell to cell, or cell to j-box, there's a failure, and the module goes open circuit. It seems that *gradual* long-term power degradation is really not happening as quickly as PV makers thought it might. According to a report from Sandia National Laboratories, the most common failure is an open circuit condition in the module (www.sandia.gov/pv/hot/qrtrep.htm).

### Simple Tests

It is virtually impossible to locate a single failed module in a large array. Even if you keep a sharp eye on the output current of the array, temperature can cause large swings in output current. I watch the meters like a hawk, and I didn't notice that one array was short a module and another was short two modules. In cases where a failed module is in series with other modules, the failed module renders the whole series string inoperative. All of our failed modules were wired up in parallel (12 volt operation).

So the lesson to be learned here is to perform a couple of simple tests on your PV modules as they reach the end of their warranty. We returned the defective modules to their manufacturers. All three of the manufacturers honored their warranties, and the failed PV modules were cheerfully and quickly replaced with brand new PVs. Joe found all the other modules up to spec in their Voc and Isc measurements.

The test procedure is very simple. All it requires is a 12 volt PV module to test, full strength sunshine, and a digital multimeter (DMM). In order to perform these tests, the PV module must be disconnected from all other modules, and from batteries and loads. Once the PV is disconnected, face it towards the sun. Then you'll be ready to make the two vital measurements that will indicate its state of health.

The first measurement is open circuit voltage (Voc). The second measurement is short circuit current (Isc). Both Voc and Isc ratings are printed on the back of almost every PV module. If your PVs don't have them, consult the documentation that came with the PV, or contact its manufacturer.

### Open Circuit Voltage

Select volts mode on the DMM, and attach the test leads to the positive and negative output terminals of the PV module. Since the PV module is disconnected from any load, what is measured is the PV's open circuit voltage. This voltage should be between 13.5 and 20+ volts DC depending on module type, module temperature, and solar insolation. If you measure less than 13.5 volts, the PV module has problems and needs to be returned to its manufacturer. In our case, all three failed modules showed zero volts during this test.

### Short Circuit Current

Set the DMM up to measure current in the amperes

range. Most DMMs these days will be able to measure up to ten amperes of current. Most PV modules will deliver no more than seven amperes, so the DMM can easily measure this without being damaged.

Attach one of the DMM's probes to the negative output terminal of the PV module, and the other probe to the PV's positive output terminal. You are essentially short circuiting the PV module through the DMM. The measured short circuit current of the module should be close to the rated short circuit current. If short circuit output current is lower than the rated value by more than fifteen percent, you have a warranty claim and the module should be returned to its manufacturer. In our case, the failed PVs showed zero current when short circuited through the DMM.

**Simple Tests, Big Rewards**
Both the Voc and Isc tests can be performed in less than a minute once the module is disconnected. All modules should have this test done a year before their warranty expires, or even more often. This test is simple and could yield the reward of a brand new module if the old one has failed. Do be sure to save all the sales receipts for all the equipment in your RE system. You'll need them if you ever have to make a warranty claim.

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**Successful Solar Businesses**
Karen and I are teaching the Successful Solar Businesses workshop once again this year at Solar Energy International (SEI) in Colorado. This is a special, two-day workshop on how to start and operate a successful renewable energy business. This will be the sixth time we've done this workshop, and the results have been fantastic. About 20 percent of the people who attend establish RE businesses within a year, and most of these businesses prosper over time.

Folks who are considering renewable energy as a career will find out what their options are. Anyone considering becoming an installing dealer of renewable energy systems will find invaluable information on not only how to get started, but also how to succeed. Those who are already installing dealers will receive specific strategies on how to build their existing businesses. We will cover a short history of the RE industry, choosing a business structure, marketing in all fashions/modes, managing a small business, managing employees, taxes, and more.

A special feature of this workshop is that attendees will make contacts with major solar energy companies right at the workshop. As of this writing, three major PV manufacturers, who are also system integrators, are sending representatives. These reps will explain what their companies can do for you as a renewable energy business person.

This is a golden opportunity for anyone who wishes to enter the renewable energy industry at any level. For startup installing dealers, the opportunity is not golden, but platinum. One of the most critical decisions installing dealers make is who their hardware suppliers will be. This workshop will help you make those essential business contacts and decisions.

Karen and I teach these workshops because we've seen RE businesses fail over the years. In most cases, these businesses went under not because the person didn't know RE technology, but because the person didn't know small business. Karen and I draw from our experiences. I spent over ten years as an installing dealer of RE systems. We started and still operate *Home Power.* Karen, in her position as *Home Power's* advertising director, speaks with hundreds of RE business people monthly, and has for over ten years now. My outline from last year's workshop is available for download from *HP's* Web page. Check it out for a taste of what we covered last time. The information we present at this workshop is drawn from the hard-won experiences of our work in the industry. If you want a career in RE, don't miss it.

Workshop dates are August 5 and 6, 2000 at Solar Energy International in Carbondale, Colorado. The tuition is US$200. Advanced registration is required and space is limited, so reserve early. This workshop is preceded by SEI's Microhydro workshop, and the Wind Power workshop taught by Mick Sagrillo. It is followed by the Photovoltaic Design & Installation and Advanced PV workshops. If you're just getting started on the road to a job or business in the renewable energy field, you should consider taking the whole series of SEI renewable energy workshops.

**Access**
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# Q&A

**Email Conversation on iMac Startup Problems**
Richard, Greetings from Alaska—cold and clear, sub-zero at night, solar power heaven. The PV panels really bust their butts to pump out power this time of year. But a curious situation has turned up and I'd appreciate your opinions.

I have a new iMac DV Special as the heart of my new computer system. Hoping to feed only the finest quality power to this and the peripherals, I bought an Exeltech 250 W sine wave inverter from Steve Willey at Backwoods Solar. It runs assorted loads just fine. Here are typical peak/running loads in watts, taken by my Brand digital power meter: Blender, 187/143; 3/8 drill, 166/166; Weller soldering gun (low), 194/125.

But the Exeltech inverter will not start the iMac, which is rated at only 125 watts maximum! The iMac starts and seems to run fine on my trusty old Trace 1512. Its power readings on the 1512 are 148 watts start, 89 boot, and 80 run; PF 0.69—well within the tested capacity of the Exeltech. Any ideas about this problem? Regards, Ed LaChapelle • Edlach@aol.com

*Hello Ed. I can only guess that the startup surge of the iMac is beyond what the Exeltech can deliver. Try using the Fluke 87 in 1 ms record mode to measure the starting surge. I'll bet it's over 500 watts. I'm not sure what time factor is involved in measuring surge on the Brand, but I'll bet it's longer than 1 ms. Also remember to factor in power factor! Try the next bigger sized Exeltech. Richard*

Ed replies: That was a shrewd guess, Richard. Adjusted for PF, the 1 ms power pulse was 560 watts. With the Exeltech 250 having only a 300 watt surge capacity, it's no wonder it didn't work. The 100 ms average surge was 300 watts. Thanks for the tip on the Fluke 87. I had forgotten about that feature for capturing peaks.

I'm trading the 250 in to Steve on a 600 watt Exeltech. The latter has 1,100 watts surge, so it should carry the startup. I also discovered that the iMac when off has a phantom draw of 0.32 amps with a PF of 0.02. This works out to about 1 watt, which is what the Brand meter reports. Apparently there is a highly reactive beast lurking in the heart of the iMac. Pushing that start button is about like creeping into his den and goosing a sleeping grizzly bear.

Thanks for taking the time to advise me on this problem. I hope the findings will be useful to others led astray by that 125 watts max label on the iMac. Do all computers have these millisecond surges, or is it just a Mac problem? My cool best wishes to all at FMI—cool from here because we're still going below zero every night. Ed

*Richard again: The surge culprit is the CRT. The high voltage power supply that supplies the anodes of the CRT has a huge in-rush current at startup. And since it is capacitors that are charging up to high voltages, the power factor is miserable. While the iMac is a great little machine for not much money, its power supply is obviously the bare minimum necessary to operate the computer.*

*I have a new CRT monitor here (24 inch Sony) that uses a step start relay and resistor circuit to minimize the startup surge. If it didn't have that step start circuit, it would* not *be able to start on a normal 15 amp, 120 VAC household circuit—it would trip the breaker. The actual computer logic and hard drive really have small startup surges. It's the CRT that's the problem.*

*We've been comparing data from a Brand meter and the Fluke 43. The Brand does a great job on power factor, but fails to capture fast surges that either the Fluke 87 or Fluke 43 will capture. Thanks for the info about the iMac being a phantom load. Richard*

Ed again: I figured the grizzly bear must have his den in the CRT; microelectronics just don't suck power like that. Sounds like a stepwise charge-up would help a lot.

Apple makes a big deal about how the iMac is silent because it has no fan. Maybe the bare-bones nature of the CRT supply has a rationale besides price in keeping down heat generation. But the land is full of fan-free 27 inch TVs that don't blow 15 amp circuits, so stepwise startup circuits must come off somebody's production line by the millions. The Exeltech 600 watt sine wave inverter has just arrived and starts up the iMac with no trouble at all. Ed

*Richard again: Apple is deep into the bean counter routine. Adding a few parts that cost the factory maybe $10 will lead to a retail price that is some $50 higher. iMacs are designed to be as inexpensive as possible. We have three of them in our new office and they work just fine and are very inexpensive. Glad to hear that your problem is solved, Ed. Richard Perez*

**Need More Acid?**
Richard, Through the normal course of a flooded lead-acid battery's life, it is discharged, recharged, and overcharged via equalization. Some of the process causes the battery to gas, releasing hydrogen, oxygen, and some of the sulfuric acid. Based on the assumed loss of acid over a period of time, how can I determine if my acid-to-water ratio is still good? John Manus • j_manus@hotmail.com

*Hello John, When the battery gases, only water is converted into hydrogen and oxygen gas; the sulfuric acid in the electrolyte remains unchanged. You can determine the acid concentration by* fully *recharging the battery and measuring the specific gravity of each cell with a hydrometer. Specific gravity should be about 1.260, which is about a 25 percent solution of $H_2SO_4$ in water.*

*You should never have to add more acid to a battery over its lifetime; you should only have to add distilled water to replace the water lost to gassing. Richard Perez*

**Use 'Em or Lose 'Em**
Hi Richard, We use an RE system that consists of twelve 75 W PV panels, twelve L-16 batteries wired for 24 V, and a Trace SW4024 inverter. We also use a 6.3 KW generator for backup during the dark months. We power several loads. The large ones include a 1/2 hp 240 VAC submersible water pump (inverter to step-up transformer) that feeds a 2,000 gallon gravity flow holding tank, front loading washer, occasional hair dryer, toaster, microwave, power tools, vacuum cleaner, and hot plate.

During sunny weather, the batteries reach full charge daily, and we use an electric hot plate for some of our cooking. This unit uses about 700 watts. We are thinking about using a larger one (1,500 W or so) that would be more useful for cooking larger dishes.

Are there any drawbacks to using batteries to power a resistance load for up to an hour or so? Your answer and comments will be appreciated. Thanks, Scott Vasak, Butte Falls, Oregon • svasak@ccountry.net

*Hello Scott, Aw Reet! Solar-electric cooking! We do the same here, only we heat water for dishes and the like. We use a 2.5 gallon point-of-use electric water heater (1,350 watts). As long as the batteries get fully recharged the next day, you do them no harm with a little electric cooking after sundown.*

*The batteries are there to serve you. While it is true that the less you use them the longer they will last, they still have a finite lifetime even if you never use them. What really counts in battery longevity is fully recharging them on a regular basis. If your system is fully recharging the battery three or four times a week, you are in fat city, and a little electric cooking will do them no harm. Richard Perez*

**Buzzzzzzz**
Dear *Home Power,* Thank you for the work you put into your magazine. I enjoy reading it very much. If you could please answer my question, I would greatly appreciate it. We have a Trace SW4048 inverter and it interferes with the short wave and AM radio frequencies on our radio. It sort of sounds like the slight buzzing sound the inverter makes when it is running, only loud—it blocks everything else out. I have read books on radios and tried to figure it out, but nothing seems to work. Do you have a solution? Thank you, Joe Hahler, Ocheyedan, Iowa

**More SW Buzzzzzz**
Dear Richard, I have a question I hope you can answer. I have a small house that I power with a Trace SW4024 sine wave inverter. Besides the lights, my main load is my stereo and TV setup. I also have a turntable and separate phone stage. As you know, a turntable operates at very low voltages and noise is easily picked up. While the sound is pretty good due to the quality of the components, I've been looking to improve the sound by adding a balanced power supply. There is a company in Selma, Oregon called Equi-tech that builds a product they claim works very well with grid supplied power.

My question is, would this treatment work the same with my Trace inverter, or would my money be better spent buying a more audio-friendly inverter like a Statpower or Exeltech? Keep up the good work, Bob Buckner, West LA, California

*Hello Joe and Bob, Radio frequency interference (RFI) is a tough problem to lick, and all inverters—without exception—have this problem. There are two basic ways that RFI travels: through the wires supplying power to the radio/stereo, and/or as radiated RF energy through space. Use a portable AM radio as a detector to sniff out what mode your RFI is using.*

*The first and most obvious solution to your problem is to use a DC (battery-powered) radio/stereo and switch off the inverter while listening to it. Not a very good solution, since you probably want the inverter operating for other appliances, and may even be powering that radio/stereo from the inverter. I've tried all manner of filters that are supposed to "clean up" the incoming power to RFI sensitive electronics. While some diminish the RFI, none has ever completely eliminated it. When it comes to RFI "hitchhiking" on the power lines, the purer the sine wave, the less the RFI. Both Exeltech and Statpower sine wave inverters produce purer sine wave power than the Trace SW series.*

*The second solution is to put some space between the radio (and its antenna) and the inverter. Radiated RFI follows the same inverse square law as all RF energy. The intensity of the RF field is inversely proportional to the square of the distance between the source (the inverter) and the receiver (your radio). So put as much space as possible between the radio and the inverter, and most especially the radio's antenna. Even a few feet can make a big difference, especially in the antenna. You can diminish the amount of RFI that the inverter is emitting by making a tightly twisted pair out of the heavy cables that supply DC power to the inverter. In my experience, these input cables are the major source of radiated, inverter-produced RFI.*

*Reducing RFI requires diligence and experimentation. Keep trying the solutions I mention here until the RFI is reduced to a tolerable level. Richard Perez*

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WANTED: A JOB in renewable energy. I have recently completed a 4 yr. degree in Appropriate Technology from Appalachian State University in Boone, NC. Please rescue me from conventional home building! References and resume available. Jay Wilson 828-963-2601.

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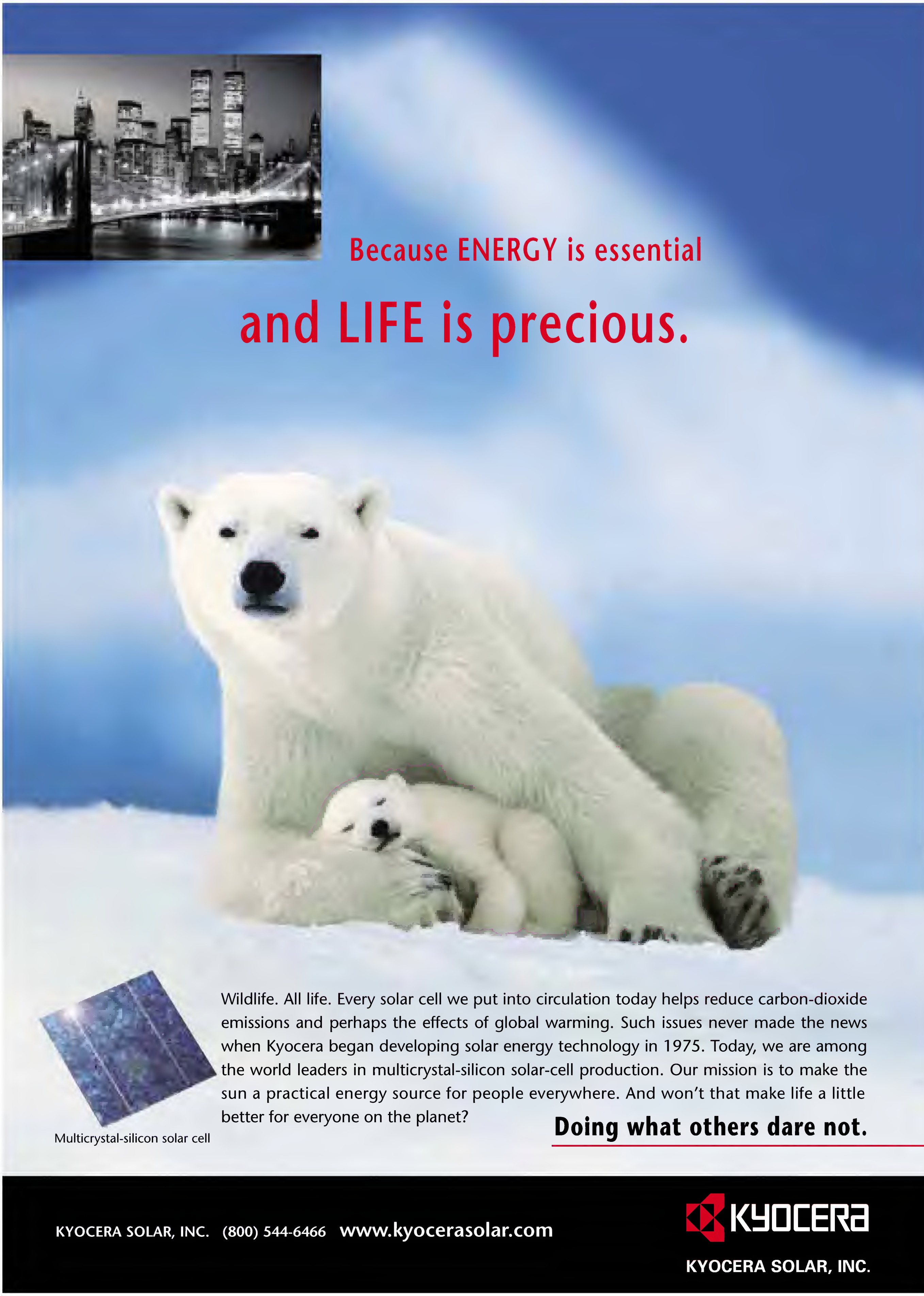
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**NOW:** I use renewable energy for (check ones that best describe your situation)

- ☐ All electricity
- ☐ Most electricity
- ☐ Some electricity
- ☐ Backup electricity
- ☐ Recreational electricity (RVs, boats, camping)
- ☐ Vacation or second home electricity
- ☐ Transportation power (electric vehicles)
- ☐ Water heating
- ☐ Space heating
- ☐ Business electricity

**In The FUTURE:** I plan to use renewable energy for (check ones that best describe your situation)

- ☐ All electricity
- ☐ Most electricity
- ☐ Some electricity
- ☐ Backup electricity
- ☐ Recreational electricity (RVs, boats, camping)
- ☐ Vacation or second home electricity
- ☐ Transportation power (electric vehicles)
- ☐ Water heating
- ☐ Space heating
- ☐ Business electricity

**RESOURCES:** My site(s) have the following renewable energy resources (check all that apply)

- ☐ Solar power
- ☐ Wind power
- ☐ Hydro power
- ☐ Biomass
- ☐ Geothermal power
- ☐ Tidal power
- ☐ Other renewable energy resource (explain)

**The GRID:** (check all that apply)

☐ I have the utility grid at my location.

I pay ______¢ for grid electricity (cents per kilowatt-hour).

____% of my total electricity is purchased from the grid.

☐ I sell my excess electricity to the grid.

The grid pays me _____¢ for electricity (cents per kilowatt-hour).

*(continued on reverse)*

**I now use, or plan to use in the future, the following renewable energy equipment (check all that apply):**

| NOW | FUTURE | | NOW | FUTURE | |
|---|---|---|---|---|---|
| ❑ | ❑ | Photovoltaic modules | ❑ | ❑ | Methane digester |
| ❑ | ❑ | Wind generator | ❑ | ❑ | Thermoelectric generator |
| ❑ | ❑ | Hydroelectric generator | ❑ | ❑ | Solar oven or cooker |
| ❑ | ❑ | Battery charger | ❑ | ❑ | Solar water heater |
| ❑ | ❑ | Instrumentation | ❑ | ❑ | Wood-fired water heater |
| ❑ | ❑ | Batteries | ❑ | ❑ | Solar space heating system |
| ❑ | ❑ | Inverter | ❑ | ❑ | Hydrogen cells (electrolyzers) |
| ❑ | ❑ | Controls | ❑ | ❑ | Fuel cells |
| ❑ | ❑ | PV tracker | ❑ | ❑ | RE-powered water pump |
| ❑ | ❑ | Engine/generator | ❑ | ❑ | Electric vehicle |

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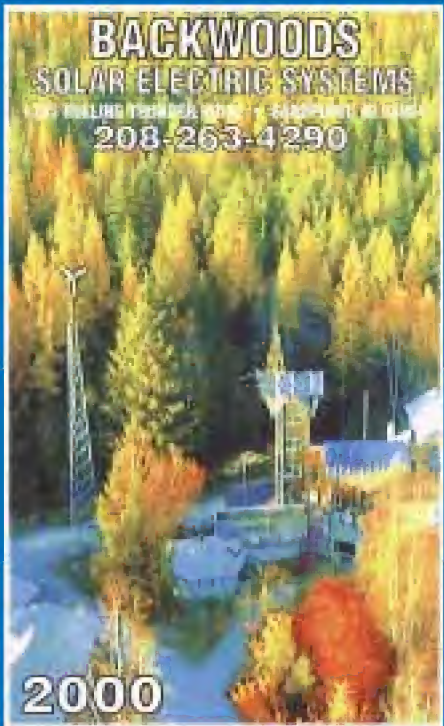


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